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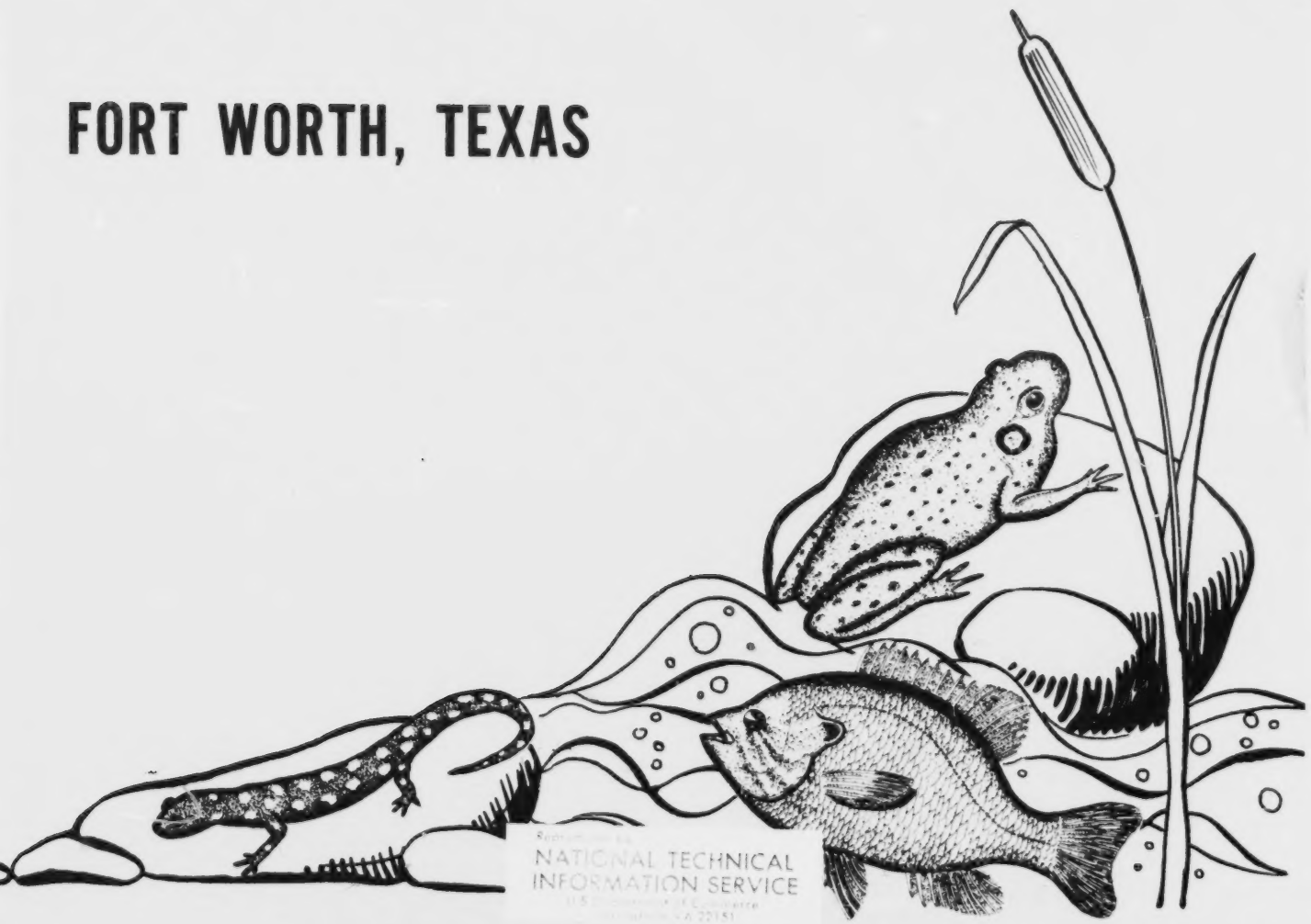
INDUSTRIAL WASTES: EFFECTS ON TRINITY RIVER ECOLOGY

FORT WORTH, TEXAS



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INDUSTRIAL WASTES: EFFECTS ON TRINITY RIVER ECOLOGY, FORT WORTH, TEXAS,

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This report was submitted in fulfillment of Project Number 18050 DBB under the sponsorship of the Water Quality Office of the Environmental Protection Agency.

*Bioassay, *Water quality, *Industrial effluents, *Water pollution, *Toxicity, *Sewage effluents, *Benthic fauna, *Seston, *Fish, Minnows, Fry, Channel catfish, Shiners, Bass, Sunfish, Fish eggs, Trace metals, Biochemical oxygen demand, Chemical oxygen demand, Conductivity, Food processing wastes, Acid wastes,

*Fish development, *Abioseston, *Bioseston, *Fort Worth, Texas, *Trinity River, *Tarrant County, Quantitative study, Distribution, Invertebrates, Turbidity, River discharge, Food processing wastes, Dissolved oxygen.

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INDUSTRIAL WASTES: EFFECTS ON TRINITY RIVER ECOLOGY

FORT WORTH, TEXAS

by

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for the

Office of Research and Monitoring
ENVIRONMENTAL PROTECTION AGENCY

Project Number 18050 DBB

December 1971

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SECTION I

CONCLUSIONS

1. Results of this 27-month investigation on the Trinity River support the generally accepted idea that the discharge of untreated industrial wastes directly into a stream of limited flow is capable of upsetting its ecological balance to the extent that populations may be almost or completely destroyed.

2. Data collected in this investigation show that certain industrial wastes do alter the composition and distribution of faunal and floral populations in a stream.

3. The Trinity River and streams of similar size usually do not have a volume of water to dilute toxic effluents sufficiently to render them harmless to the river biota. This was especially true with respect to Stations I, III, V, and VII.

4. Effluents containing fuel oil, grease, and detergents such as that from Station I, a railroad equipment cleaning area, are quite toxic to fish and benthic organisms. Effluent from this particular station varied in quality but toxicity remained consistently high.

5. The following parameters of the Trinity River, pH, COD, BOD, phosphates, and specific conductance, were affected by effluents containing detergents, grease, and fuel oils.

6. Untreated or improperly treated sewage has adverse effects on fish as observed in this study at Stations II and VII. The adverse effects appear to result from oxygen depletion rather than direct toxicity. Test organisms survived in 100% concentration of the effluents when aerated.

7. Storm sewer effluent (Station II) did not appear to have an appreciable effect on the Trinity River. However, conductivity of the effluent was high and there was a slight rise in COD and nitrate values downstream from the outfall.

8. Floc in effluent from a catalyst producing plant (Station III) greatly altered the environment in the vicinity of the outfall and for a considerable distance downstream. This was evidenced by fish floating lifelessly in the effluent plume and presence of benthic organisms from midstream to the bank opposite the outfall. The current usually did not permit the effluent to spread over the entire width of the river.

9. Station III effluents contained chemical substances that exerted very adverse effects on the flora and fauna. These effects were apparent for a considerable distance downstream. Flocculent material in this effluent accumulated around the gills of fish. This suggested possible adverse effects of a physical nature. Laboratory tests using supernatant fluid showed less toxicity to test organisms than the intact effluent.

10. Effluent from Station III stored for several days under laboratory conditions showed no reduction in toxicity.

11. Fish exposed to Station III effluent suffered direct injury to the gills. Blood was released from the gills and rather extensive gill tissue erosion resulted from relatively short exposure in laboratory tests.

12. Station III effluent affected the chemistry of the river water with respect to the following parameters: pH, conductivity, alkalinity, COD, nitrates and orthophosphates.

13. The volume of suspended material in Station III effluent that may settle out was sufficient to impair benthic life regardless of toxicity.

14. Station III, as of July 1, 1971, diverted its waste effluents into the sanitary sewer and through the sewage treatment plant. The region near the outfall is clearing and in time populations are expected to become established in areas formerly not inhabited.

15. Effluents from a plant primarily engaged in metal etching (Station VI) were the most toxic of the effluents tested as demonstrated by response of catfish eggs, fry and mature minnows. The buffering effect of lime dumped into Station VI holding pool reduced toxicity of this effluent for fish. It is concluded that direct discharge of Station VI effluent into the Trinity River would have widespread effects on the river biota.

16. Any combination of equal amounts of effluents from Stations I, III and VI show antagonism. However, because of distance between the respective industries, the ill effects of one may not be countered by another.

17. Results from laboratory experiments indicate that fish spawn and fry serve well as test organisms in bioassay work. However, limited time of availability is possibly the greatest drawback to their use.

18. Laboratory observations suggest that embryonic membranes of prehatched fish afford considerable protection against the various industrial effluents studied.

19. Fry surviving bioassay tests of Station I and III effluents lived for periods up to 10 weeks when transferred to holding aquaria. Some of these fry developed marked orientation problems while others showed considerable variation in growth.

20. Sewage treatment plant effluents (Station V) caused a drastic reduction in population at the outfall. Chlorination of the discharge is believed to have contributed appreciably to the adverse effects on the biotic community. The effluent also altered BOD, COD, and phosphates of the river water.

21. Effluents from a food packing plant and other light industries discharged into a tributary (Station X) apparently had no significant effect on the Trinity River. Chemically, a slight increase in ortho-phosphates was noticed.

22. Toxicity of a chemical company primarily engaged in production of acids appeared to be held well under control as long as their present treatment system (buffering) functioned properly.

23. Station VII, a sewage treatment plant, is very ineffective in its present state of repair. Diversion of its effluent to the Fort Worth sewage treatment system will alleviate any problem associated with it.

24. Organic materials from the stockyards and meat processing plants made conditions favorable at the mouth of a small tributary (Station IX) for large numbers of Tubificidae but decreased diversity of benthic organisms. Nitrate and specific conductance values in the Trinity River were increased below the mouth of this tributary.

SECTION II

RECOMMENDATIONS

The Trinity River in the study area, Tarrant County, Texas, is a stream with limited volume of flow. Since the Trinity River is the sole avenue for transporting industrial and domestic wastewater from the area, great stress is placed on it especially during the months of low rainfall. Although all industries in the area do not discharge their wastes directly into the river, those that do plus discharge from sewage treatment plants somewhat likens the river to an open sewer in places. To alleviate this situation by closing an industry or industries is not necessarily the best solution to the problem.

There are several ways by which pollution abatement may be promoted. Recommendations that will reduce or possibly eliminate pollution for those industries that discharge wastewater directly into the Trinity River or any other stream are as follows:

1. It may be economically feasible to recover some of the basic materials from the effluent for reuse thus improving the quality of the wastewater. A chemical plant discharging at Station III has initiated this procedure since the beginning of this investigation. This practice should be given careful consideration by any industry whether or not it discharges wastes directly into a stream or uses the sanitary sewer system.

2. Wastewater may be reclaimed for reuse. Such is recommended especially in this general region. It serves as an available source of water and lessens pollution. Companies using great amounts of water such as the railroad equipment cleaning area at Station I and the chemical plant at Station III may find it economically feasible to consider this procedure.

3. Effluents may be held in pools permitting suspended materials to settle and partially degrade prior to release. The railroad cleaning facility uses a detention pool. Because of the high toxicity of its effluent and the fact that effluent is discharged into the river below a dam where flow is usually extremely limited, it is recommended that the holding pool be increased in size permitting maximum degradation before being released. It is further recommended that oil and grease floating on the surface be siphoned off periodically and not permitted to enter the pipe line to the Trinity River. Even under present conditions the effluent should be released on a more gradual basis over extended periods so that the impact on the river is not so great.

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4. The pollutant may be either removed from the effluent or treated to render it less toxic. The metal etching plant at Station VI uses a holding pool and treats the effluent from time to time with lime. Since the effluent is still usually very acid from one area, a more systematic and efficient buffering system should be considered. A chemical company discharging at Station IV uses such a system with favorable results. Not only the industries involved in this investigation but those in other areas as well should study their processing procedures to determine changes that might be made which would eliminate, or at least reduce the release of pollutants in the process fluid.

5. Untreated and improperly treated sewage periodically enters the Trinity River at Station II and Station VII. Every effort should be made to prevent such material from being discharged into the Trinity River.

6. It is recommended that results of this investigation be made available to all industrial plants which discharge into the Trinity River at stations mentioned in this report.

7. Additional studies should be made similar to this one to cover a greater number and variety of industries. This would give a more complete picture of the pollution situation along the upper Trinity River and serve as an index of what may be taking place along other streams of similar flow through an area of comparable industrialization. The study should include long range survival of fry exposed to various polluting effluents.

SECTION III

INTRODUCTION

Since water supply, water pollution control and water reuse are so important and vital to future economic growth, health and welfare, Kalinske (1967) expressed concern that our nation had allowed the existing water situation to become as critical as it has today. Despite the fact that our water situation may be less than desired, problems concerning water pollution were recognized over 100 years ago. Penny and Adams (1863) investigated pollutants in the River Leven. However, it was not until after the turn of the century that Shelford and Wells began to concern themselves with related experimental work in this country. As related by Mackenthun (1969), "Water quality affects man in his direct use of the water; it affects also the aquatic life that water contains".

The presence or absence of living organisms in accordance with their individual demands and tolerances might well be indicative of water quality. Disregard for aquatic life could result in compounded problems with respect to pollution abatement. Pollution and overfishing have almost destroyed the fishery industry in Lake Erie and domestic wastes have essentially obliterated shellfish industry of the upper Mississippi Valley (Black, 1968).

Pollution damage results from three major causes - domestic, agricultural and industrial wastes. Domestic and agricultural wastes are quite common and widespread. Industrial pollution is very diverse and critical. Hart, Doudoroff and Greenbank (1945) wrote a book dealing with this aspect.

Among domestic wastes, detergents, soaps, liquids and organic substances passed through disposals get into the sewer system and eventually into streams. The effects of synthetic detergents and soaps on fish varies with the type substance and quality of water (hard/soft). Henderson, Pickering and Cohen (1959) found that some household soaps were more toxic to fathead minnows in soft water than synthetic detergents but less toxic in hard water. Respiratory stress seems an apparent reaction to synthetic detergents. Although detergents do not appear to have a lethal potential comparable with cyanides, heavy metals and insecticides, the increase in use and possible indirect effects on aquatic life deems it necessary to keep detergents under constant surveillance.

Ingredients of fertilizers such as phosphates and other chemicals, silt eroded from cultivated fields and pesticides of various types are among the agricultural wastes. The use of insecticides and herbicides is increasing and is posing problems with respect to aquatic life. Toxicity of insecticides is greater on a specific quantity basis (ppm)

than herbicides (Jones, 1966). However, the use of herbicides for control of aquatic plant life must be in such high concentrations that they approach the lethal level for fish and other fauna. Henderson, Pickering and Tarzwell (1959, 1960) did extensive work with chlorinated hydrocarbon insecticides using bluegills, guppies and goldfish as test organisms. Bluegills were most sensitive to the chemicals and endrin was the most toxic of the insecticides. A comparison of toxicity of organophosphorus insecticides to fish with that of chlorinated hydrocarbons has shown that the latter are more toxic. Organophosphorus insecticides are less stable in water than chlorinated hydrocarbons which make them less dangerous to fish.

Industrial wastes are too numerous to name all but include lubricating oils, grease, acid, alkali and heavy metals such as mercury, copper, lead, zinc and others. The effects of heavy metals such as lead, copper, zinc and others have received considerable attention. Lead, copper and zinc have proved to be very toxic to various organisms. Doudoroff (1952) demonstrated that a mixture of copper and zinc has a synergistic effect on minnows (Pimephales). Jones (1938) demonstrated that lead reduces the toxicity of copper to various freshwater invertebrates. Calcium reduces the toxicity of certain heavy metals, especially copper. According to Mount (1968), results of bioassays made only in soft water may be misleading.

With the increase in pollution and realization of its seriousness, field and laboratory work have been instituted to obtain useful information concerning source, type and control. Some of the early work was done along the Illinois River by Forbes and Richardson (1913, 1919) and by Forbes (1928) especially pertaining to organic pollution. Richardson (1921) described variation in bottom fauna of the Illinois River resulting from increased movement of sewage pollution. Purdy (1916) demonstrated the value of certain organisms to indicate sewage discharges in the Potomac River. Organic enrichment of running waters and abrupt changes in biota following introduction of waste materials were reported by Weston and Turner (1917), Butterfield (1929) and Butterfield and Purdy (1931). They pointed out that as the wastes were consumed or utilized there was gradual recovery of the biota downstream.

Species diversity and population studies have been used in several instances to show proof of disruption of water quality suitable for aquatic life. Cross and Braasch (1969) reported a great decrease in the fish population in the Neosho River, Kansas between 1952 and 1967. The greatest deterioration of the population occurred in an area where previous fish kills had been reported due to cattle feed lot runoff. Fish kills were reported by Williams et al. (1966) in the Ohio River in the summers of 1962-1964. These fish kills were attributed to organic matter and heavy metal accumulation in deep pools during periods of low flow. The accumulation created serious problems during periods of high flow when the organic matter and heavy metal went into suspension, and in conjunction with higher temperatures, the lowering of dissolved oxygen (DO) occurred.

Wheeler (1969) reported a decline in the fisheries on the Thames River and attributed this to pollution. A winter fish kill in a reservoir in Iowa was reported by McDonald and Schmickle (1968) and the ascribed cause was high oxygen demand in runoff water. Kussat (1969) surveyed two regions of the Bow River in Calgary, Canada, one region upstream from Calgary, and the other below Calgary. He observed a reduction of species of benthic invertebrates, changes in the chemical nature of the river, and an increase in the condition factor for rough fish downstream from Calgary. These changes were attributed to industrial and domestic waste discharges. The effects of coal washer water in Kentucky were observed by Charles (1966). He reported that bottom fauna used as fish food were reduced, and that the predominant fish in the polluted region were channel catfish and suckers. Tsai (1968) observed that discharge of chlorinated wastewater into the upper Patuxent River in Maryland acted as a toxic material initially, reducing fish species diversity and abundance below the outfall. Downstream the water was de-oxygenated due to enrichment.

Other studies have been done on various industrial effluents to determine their toxicity to fish. Toxicity studies on refinery effluents were conducted by Graham and Dorris (1968) on fish. They reported adverse effects from sub-acute concentrations of effluents over lengthy exposures. Patrick et al. (1968) studied the effects of twenty common industrial effluent components on diatoms, snails and bluegill sunfish. They reported various levels of sensitivity by all these organisms and for several components, the sensitivity difference between the three organisms was quite pronounced. Not all effects of effluents are detrimental. Beadles (1966) observed that when wastewater from a refinery was diluted to a certain level the size of the fish increased. It is also common knowledge that certain nutrients are very beneficial when present in tolerable concentrations. From this it can be seen that industrial and domestic waste discharges present complex problems and more than one factor may be involved.

Maintenance of the biotic community is necessary for proper ecological balance. Destruction of the populations retards uptake and/or decomposition of polluting substances in the water, thus prolonging their effects and time the material is present. Bartsch and Churchill (1949) described biotic response to stream pollution and associated aquatic organisms to zone of degradation, active decomposition, recovery and clean water. Patrick (1949) also described regions of the stream in relation to pollution, separated biota into groups and illustrated group response to stream conditions. As pollution progresses, bottom life changes. Those organisms sensitive to a specific pollutant cease to exist and are succeeded by more tolerant ones. Lagler (1956) lists tubificid worms, leeches, mosquito larvae, rat-tail maggots, filterfly larvae and fungus as the organisms more nearly to become dominant in the regions of organic pollution. However, Gaufin and Tarzwell (1952) state that because of the wide range of natural situations that these organisms inhabit, they may not always be true indicators of polluted areas.

The Clear and West Forks of the Trinity River converge near the center of Fort Worth and continue along a winding course through Dallas. Approximately 700 industrial plants ranging from a few employees (less than ten) to more than 5,000 located in Fort Worth, discharge their waste effluents either directly into the Trinity River or indirectly through Municipal Treatment Systems which discharge into the river. Approximately 200 more plants of varied sizes are located in the urban area between Fort Worth and Dallas (F.W.C.C., 1968). Domestic wastes from the urban districts are also discharged through treatment plants into the river. The Trinity River, limited in size, is the sole avenue for transport of waste effluents from the Fort Worth Area (Figures 1 and 2). The stress placed on the Trinity River is greatly increased during the summer months when rainfall is reduced to a minimum. The availability of a ready supply of usuable fresh waster greatly influences urban and industrial planning. The biota of a body of water contributes to the maintenance of a balanced system. Fish play a significant role in perpetuating ecological equilibrium.

This report summarizes 27 months of research directed toward qualitative and quantitative effects of certain industrial waste effluents being discharged directly or indirectly into the Trinity River on selected species of fish and other biota. To obtain a broader picture of impact of the effluents, the project was divided into four facets: bioassay, chemistry, growth and development, and benthos. Information gained about parameters associated with the above categories will provide evidence concerning toxic potential of the type pollutants for the organisms involved and possibly facilitate the formulation of water quality standards.

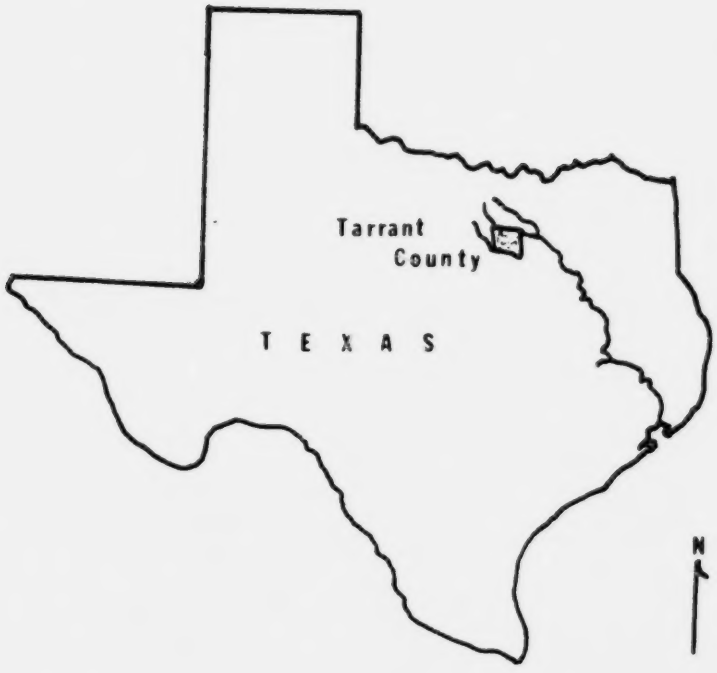


Figure 1: Map of Texas showing Trinity River system.

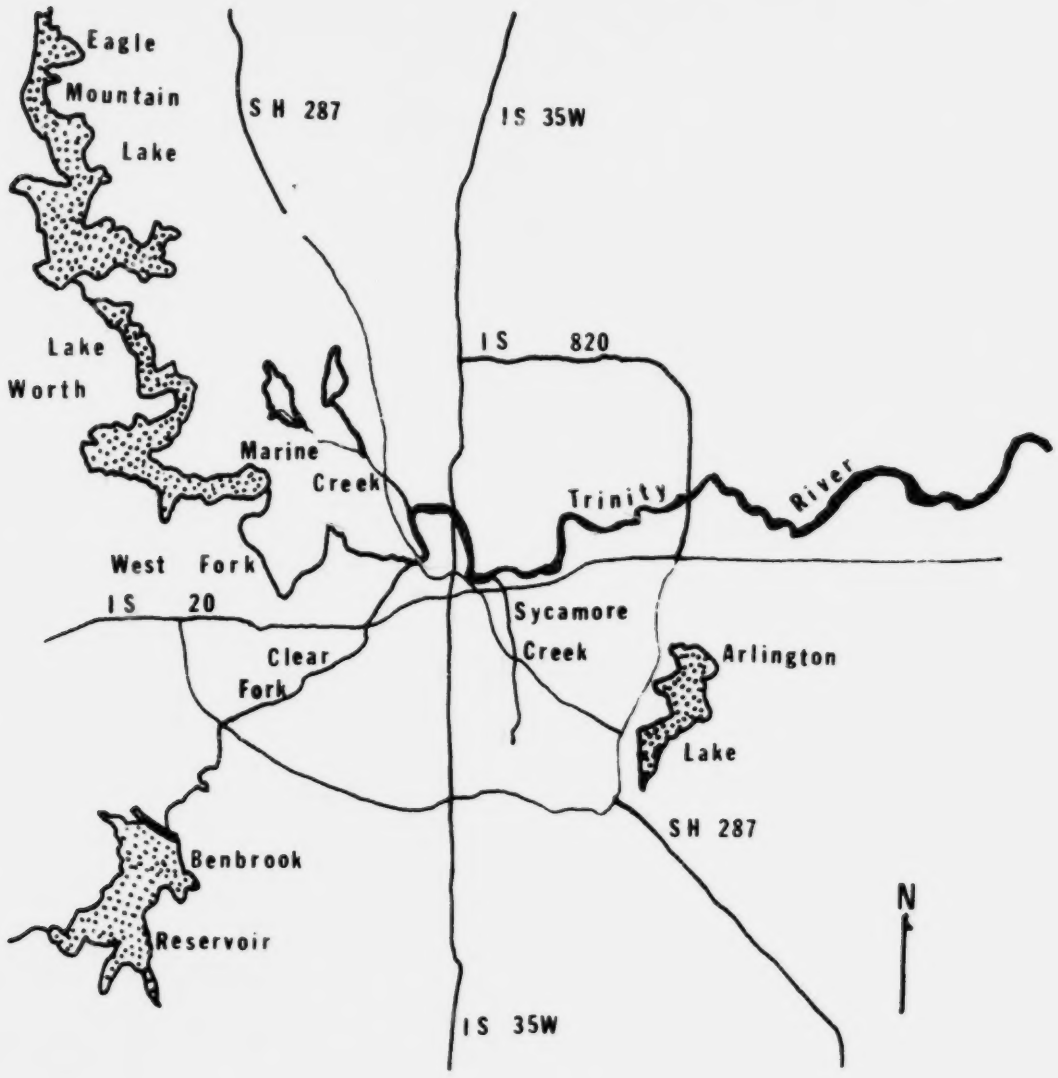


Figure 2. Map showing Trinity River course through Tarrant County.

SECTION IV

METHODS AND MATERIALS

Bioassay

The toxicity of complex waste effluents from industrial plants was determined by bioassay and the results (TL_{50} - median tolerance limit) expressed as per cent. Both static and continuous flow through methods were used.

Effluents were collected in the field in 5 gallon glass containers and returned to the laboratory for processing. In order to avoid the selection of solutions that might cause direct injury to test organisms, static bioassay tests were conducted. A series of five concentrations (100%, 75%, 25%, 12.5% and 6.25%) were used in the test. Two liters of the respective concentrations were placed in wide mouth 1 gallon glass jars along with two test organisms (fish). The lowest concentration in which both test organisms were killed was selected as the highest concentration to be used in the continuous flow system.

The continuous flow system used is a modification of the system described by Mount and Brungs (1967). Modification was necessary in order to deliver the large quantities of pollutant required. Diluent water used was Fort Worth City water. A carbon filter was installed in the water line to remove the chlorine. After moving through the carbon filter the water passed slowly through a column of bone charcoal. Approximately 200 gallons of filtered water was held in reserve.

The continuous flow system was equipped with six glass test tanks, each with a capacity to the overflow of 20 liters. The complete volume of fluid in each tank was replenished about six times in the course of 24 hours. The systems were arranged so that two series or duplicate tests could be conducted concurrently. Each system had its own control tank.

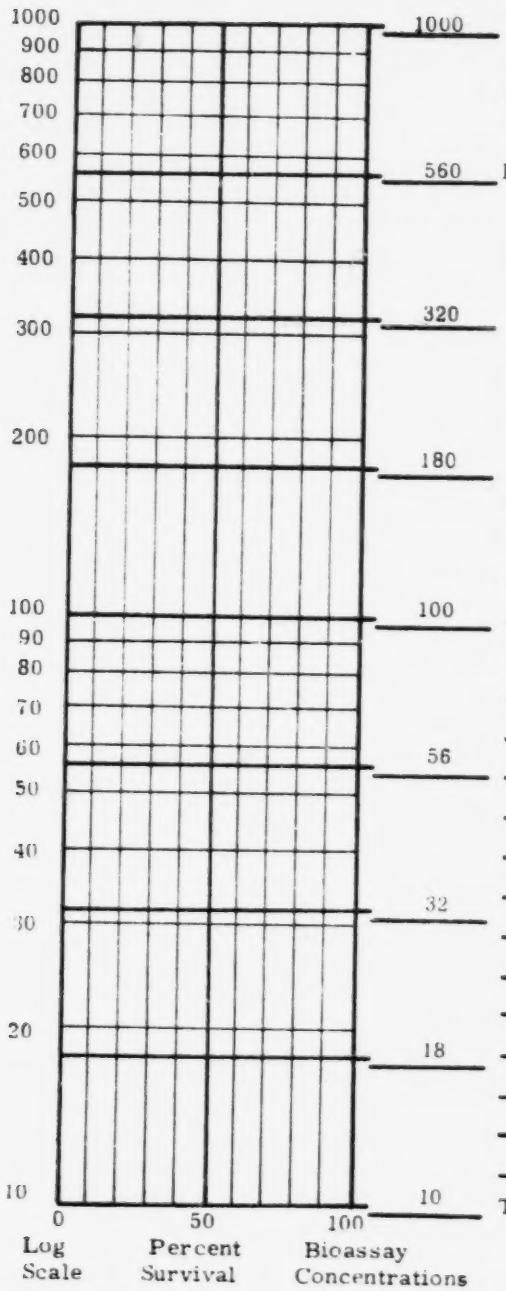
The test organisms (fish) were weighed in order to insure reasonably uniform size. Ten fish were placed in each test chamber and the control tank. This number made the results statistically significant. The TL_{50} (concentration of toxicant in water that causes 50% mortality of the test organisms in specified periods of time) was estimated from observed mortality. Twenty-four, 48- and 96-hour time periods were used. The fish were removed from the test chamber when dead. Deaths were recorded each 24 hours. Using semi-log paper (Figure 3) the concentration was plotted on the log scale against survival on the arithmetic scale. Fifty per cent survival concentration was estimated by a straight line graphical interpolation. The result is a direct

Figure 3

TL_m PAPER

(Semi-log)

Sheet No. or Code: _____



Material Tested: _____

_____

Starting Date: _____ Hour: _____

Final Results: TL_m

	Time Intervals		

Concentrations Expressed as (circle one):

%, mg/l, other: _____

Test species: _____

Temperature Range: _____

Dilution Water (source & characteristics):

_____

Notes: _____

_____

_____

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comparative measure of toxicity under test conditions. A copy of the semi-log paper was obtained through the Environmental Protection Agency Water Quality Office in Cincinnati, Ohio, and duplicated.

The test organisms used in the bioassays were golden shiner (Notemigonus crysoleucas (Mitchill)), fathead minnows (Pimephales promelas Rafinesque), largemouth bass (Micropterus salmoides (Lacepede)), channel catfish (Ictalurus punctatus (Rafinesque)), and hybrid sunfish (longear - Lepomis megalotus (Rafinesque) and green sunfish - Lepomis cyanella Rafinesque). The fish were obtained from the Fort Worth National Fish Hatchery, Eagle Mountain Fish Hatchery and the Blue Top Minnow Station. The chief sources of fish for the latter were fish hatcheries in Arkansas. The fish were retained in a holding tank in the laboratory for approximately 10 days to become acclimated to laboratory conditions prior to use.

Turbidity was determined by a Hach Turbidimeter Model 2100 and values expressed in Jackson Turbidity Units (JTU). A Sargent Portable pH Meter was used to determine pH. A Yellow Springs Instrument Company Model 54 Oxygen Meter was used to determine dissolved oxygen which was expressed in parts per million (ppm). Other chemical parameters were determined according to procedures in Standard Methods for the Examination of Water and Wastewater (12th Edition) and FWPCA Methods for Chemical Analysis of Water and Wastes, November, 1969.

Total seston was determined by the ignition method. The suspended solids were removed from 4,000 ml of effluent by passing it through a Foerst continuous flow centrifuge. The residue was transferred to a previously desiccated and weighed crucible. Fluid was evaporated from the residue in an oven at approximately 130°F. After desiccation and weighing the residue was placed in a muffle furnace and the temperature was raised to 750°C. It was then cooled in a desiccator and weighed. From the three weights, total seston, abioseston and bioseston were calculated and expressed in milligrams per liter (mg/l).

Specific conductance was determined by using an Industrial Instruments, Inc. Model RB3 Solu Bridge. The values are expressed in micromhos per centimeter.

Growth and Development

Fish spawn and fry used were those available from the Fort Worth Federal Fish Hatchery. Bass fry (Micropterus salmoides) averaging 21 mm in length were available in mid May of 1971 and channel catfish (Ictalurus punctatus) eggs and fry from two or three different spawnings were available in June of both 1970 and 1971. One unsuccessful attempt was made in March 1971 to use amphibian eggs as test material.

Most of the catfish eggs were brought into the laboratory in cooled containers some four to five days prior to hatching where they were

separated into reasonably small clusters before transferring to holding aquaria. Thus they were available for some test runs prior to hatching and other runs at various periods after hatching.

All tests (TL_{50}) on eggs and fry were carried out at the same time bioassays were being run on mature minnows or other fish. A modification of the proportional diluter described by Mount and Brungs (1967) was employed for all tests. Two batteries of six tanks each were available at the beginning of these studies which permitted duplicate test runs with the same effluent. By late June of 1970 two other batteries of six tanks were completed permitting two duplicate test runs using two different effluents. Dilutions of effluent used for each test were based on static tests using mature minnows. Conducting tests on fry simultaneously with tests on mature fish permitted later comparison of survival values between immature and mature organisms.

Eggs and fry were suspended in clear plastic cups in each dilution of the effluent. These cups were 3 inches high and tapered from 3 inches in diameter at the top to 2 1/4 inches at the bottom. In the first preliminary tests of 1970 the bottoms of these cups were removed and replaced with silk bolting cloth. It was discovered in this initial test run that the bolting cloth did not permit ready circulation of fluid through the cups particularly when the effluent contained flocculent precipitates. The cups were redesigned by leaving the bottoms intact and drilling a number of 1/16 inch holes in the bottoms and some half way up the sides. An average of 16 of these holes were drilled in the bottom of each cup and 28 in the sides. It was found that the drilled cups when submerged to a depth of about 2 inches did permit adequate circulation of fluid through the cup during the course of the test and in general gave a satisfactory performance.

The optimum number of test organisms per cup presented a problem in the early stages of study. After the first two test runs where 20-50 eggs per cup were used the number was reduced to 10 per cup and this worked well for most of the remaining tests. In the case of the bass fry tested in May 1971, it was found desirable to reduce the number of fry to five per cup and to suspend two or more cups per tank.

During each test dead fry were removed from the test cups at regular intervals, examined visually under low magnification for damage and then preserved in 8% formalin for future study. Beginning with Series VIII (June 1971) survivors from each cup for each test were transferred at the end of the test to individual floating cups which were maintained in the holding aquarium for periods up to 10 1/2 weeks. Fish were fed daily and observed for morphological changes. Periodic survival counts were made and dead fry were preserved in formalin. The floating cups used here consisted of "SPECTRUM" white plastic cups measuring 3 inches in diameter and 2 inches deep. Approximately two dozen holes (1/16 in.) were drilled in the bottom of each cup and an additional 20 holes drilled in the lower half of the sides. Four small styrofoam floats

were attached to each cup just below the rim. The cups floated freely, permitting adequate circulation of water through the pores and were easily cleaned.

Chemistry

Samples were taken from two areas on the Clear Fork of the Trinity River and from four areas on the Trinity River below the junction of the Clear and West Forks of the Trinity River. Station I is an effluent from a railroad equipment cleaning area which enters the Clear Fork of the Trinity River just downstream from the new Vickery Street dam (Figure 4). An outfall from a storm sewer receiving effluents from small industries and some untreated sewage is Station II (Figure 5). Station III is an outfall from a chemical plant which manufactures cracking catalysts and enters the Trinity River just downstream from the North Main Street viaduct (Figure 6). A sewage treatment plant outfall represents Station V (Figure 7) while Stations IX and X are tributaries which empty into the Trinity River (Figures 8 and 9). Each of these sampling areas or stations were subdivided into five substations: one substation upstream from the outfall designated as "A", a second substation at the outfall designated "B", a third substation designated "C" at the point of initial mixing of the discharge with the river, and fourth and fifth substations designated as "D" and "E", respectively at a distance of 200-400 yards and 400-800 yards, respectively from the point of discharge. All samples were taken in order "A", "B", "C", "D" and "E" within the shortest possible time. Subsequent samples at a station were taken at two day intervals except when weather conditions, high water or construction prevented sample collection. Samples were marked as "A", "B", "C", "D" and "E" for the first series of samples then "A_2", "B_2", "C_2", "D_2" and "E_2" for the second series and so on through five series of samples for each station.

Three series of samples were taken at Station V, the sewage treatment plant, before it was realized that there were two discharge outlets for this plant. After this, four series of samples were then made up of nine samples each. The first three series were designated in the same manner as the other stations, but the next four series of samples were made up of nine samples. Since this newly discovered outfall was upstream, four new substations were designated. Substation "A*" was upstream from the new outfall, "B*", new outfall, "C*", initial point of mixing of new outfall and stream, and "D*", about 250 yards downstream from the new outfall. The original Substation "A" was redesignated as "E*" and was located about 400 yards downstream from the south outfall and about 40 yards upstream of the north outfall. The original "B", "C", "D" and "E" remained the same. The new series was numbered "A_4*", "B_4*", "C_4*", "D_4*", "E_4*", "B_4", "C_4", "D_4" and "E_4". The asterisk designates the new stations from those downstream. This series continued through "A_7*", "B_7*", "C_7*", "D_7*", "E_7*", "B_7", "C_7", "D_7" and "E_7".

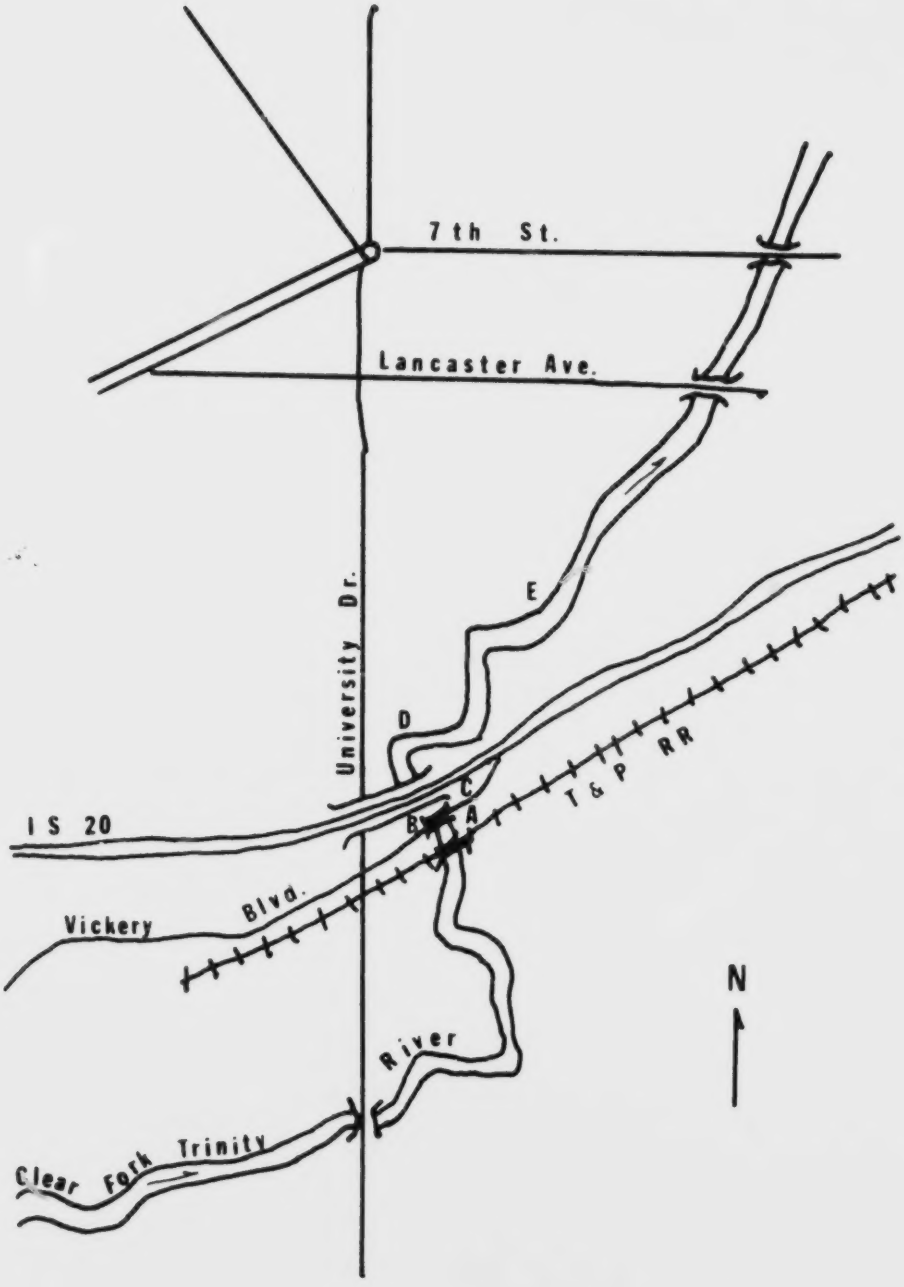


Figure 4. Map of Station I showing substations.
Scale: 1 inch = 2,000 feet.

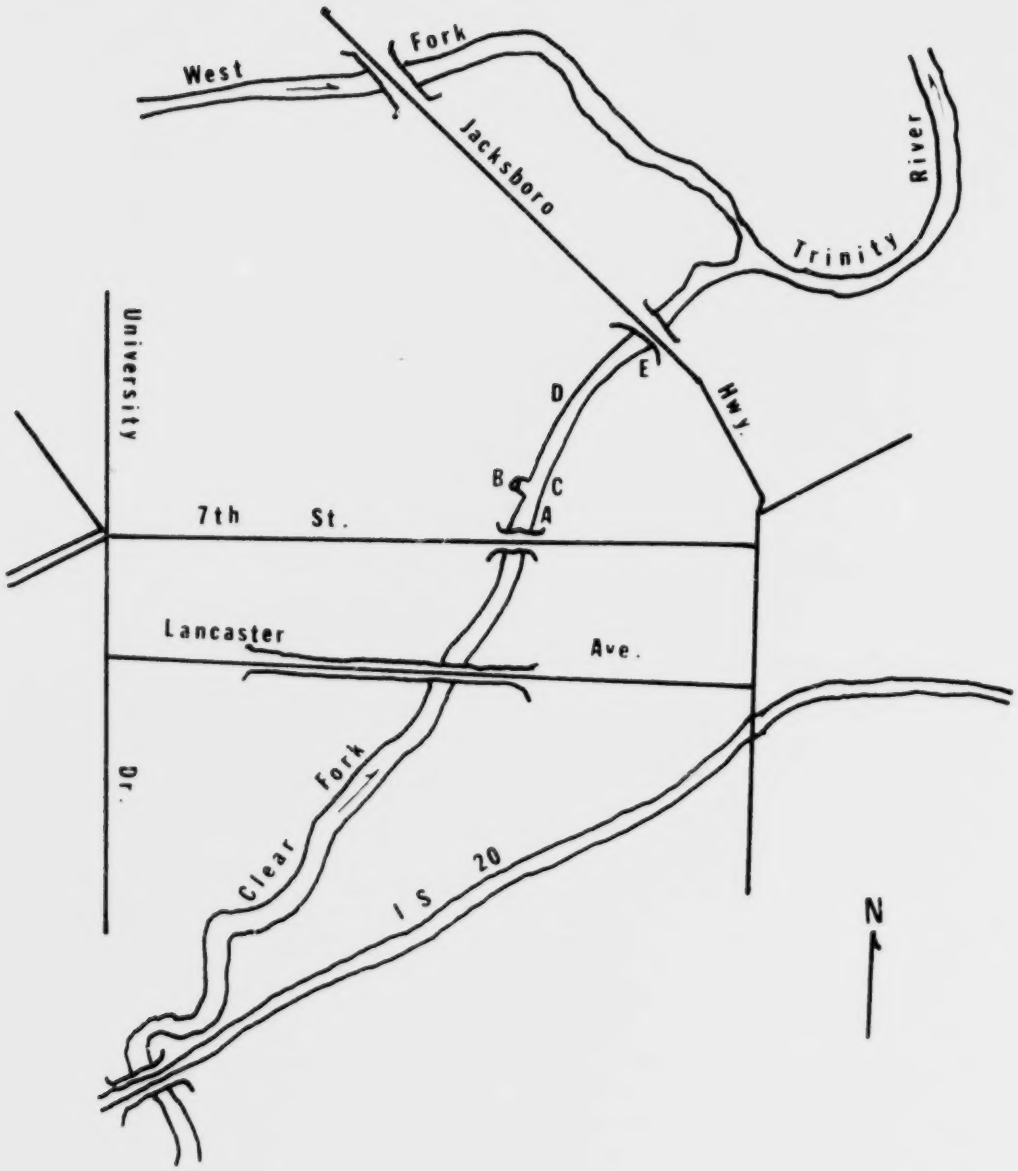


Figure 5. Map of Station II showing substations.
Scale: 1 inch = 2,000 feet.

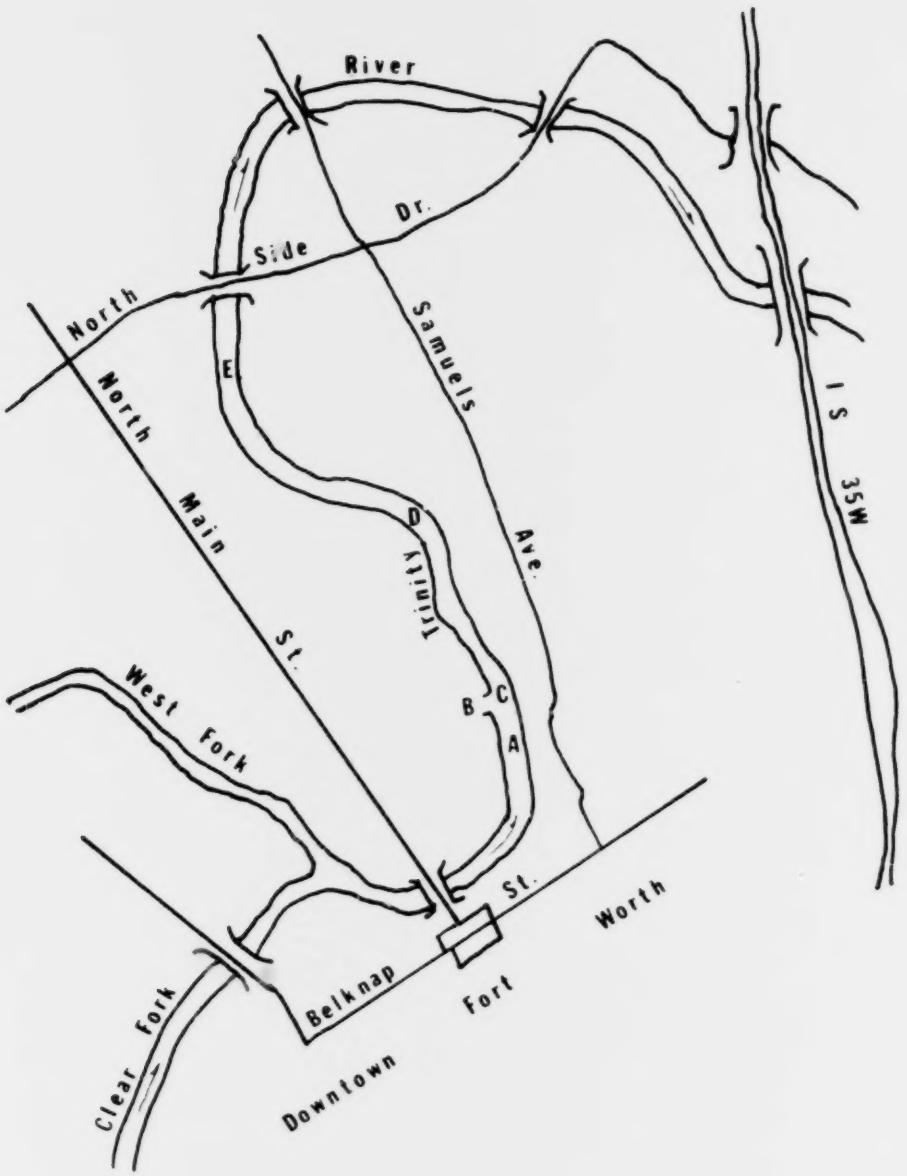


Figure 6. Map of Station III showing substations.
Scale: 1 inch = 2,000 feet.

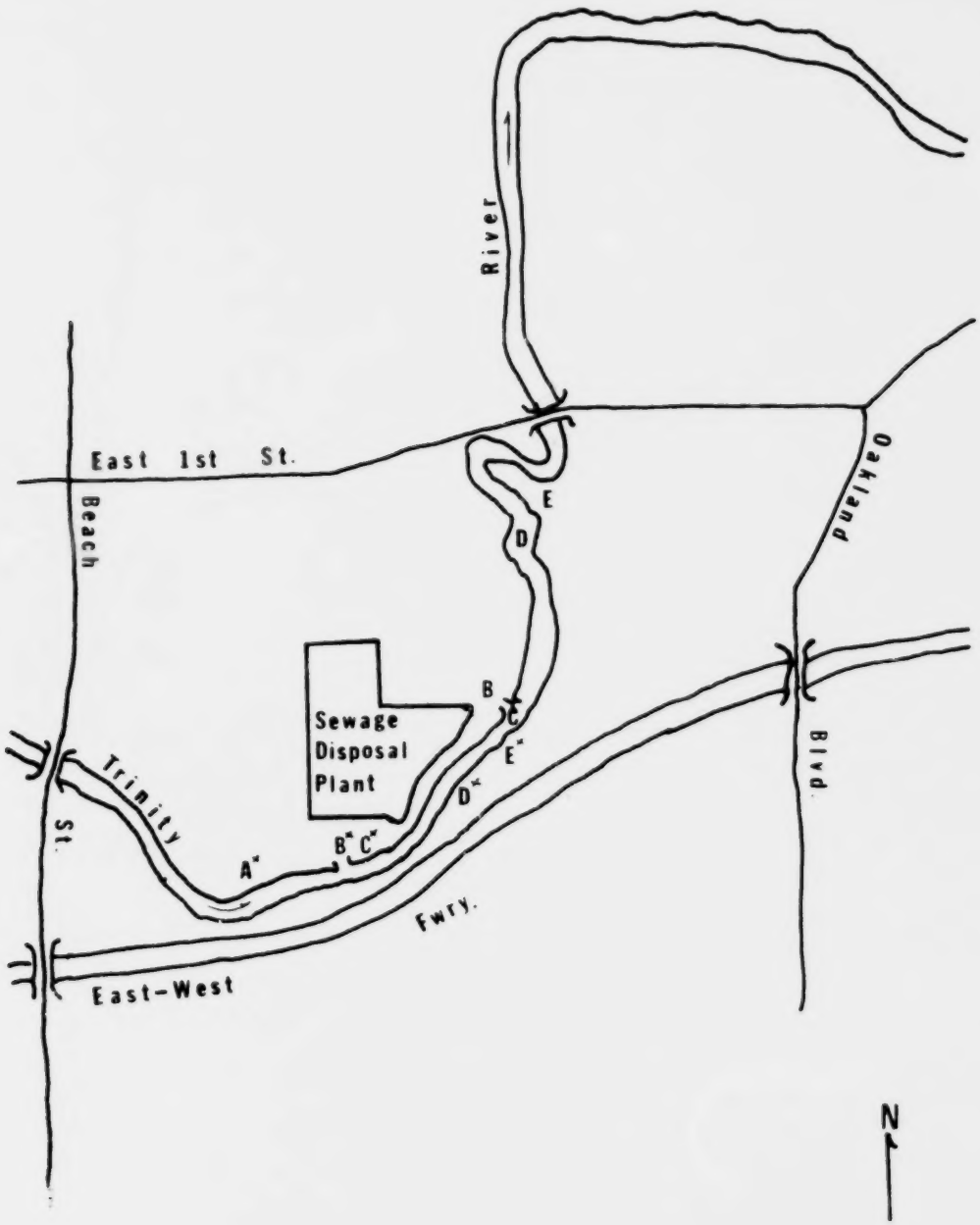


Figure 7. Map of Station V showing substations.
Scale: 1 inch = 2,000 feet.

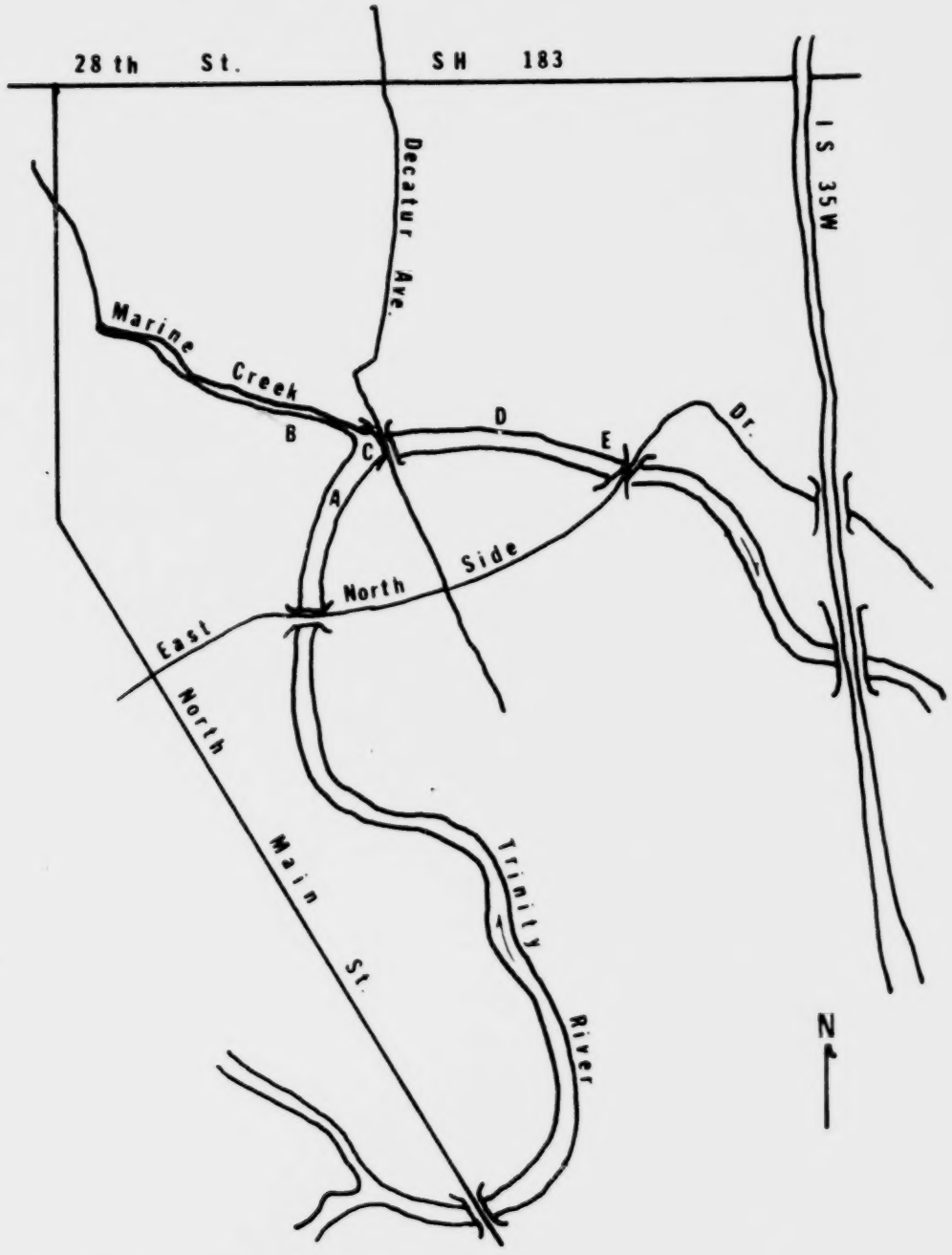


Figure 8. Map of Station IX showing substations.
Scale: 1 inch = 2,000 feet.

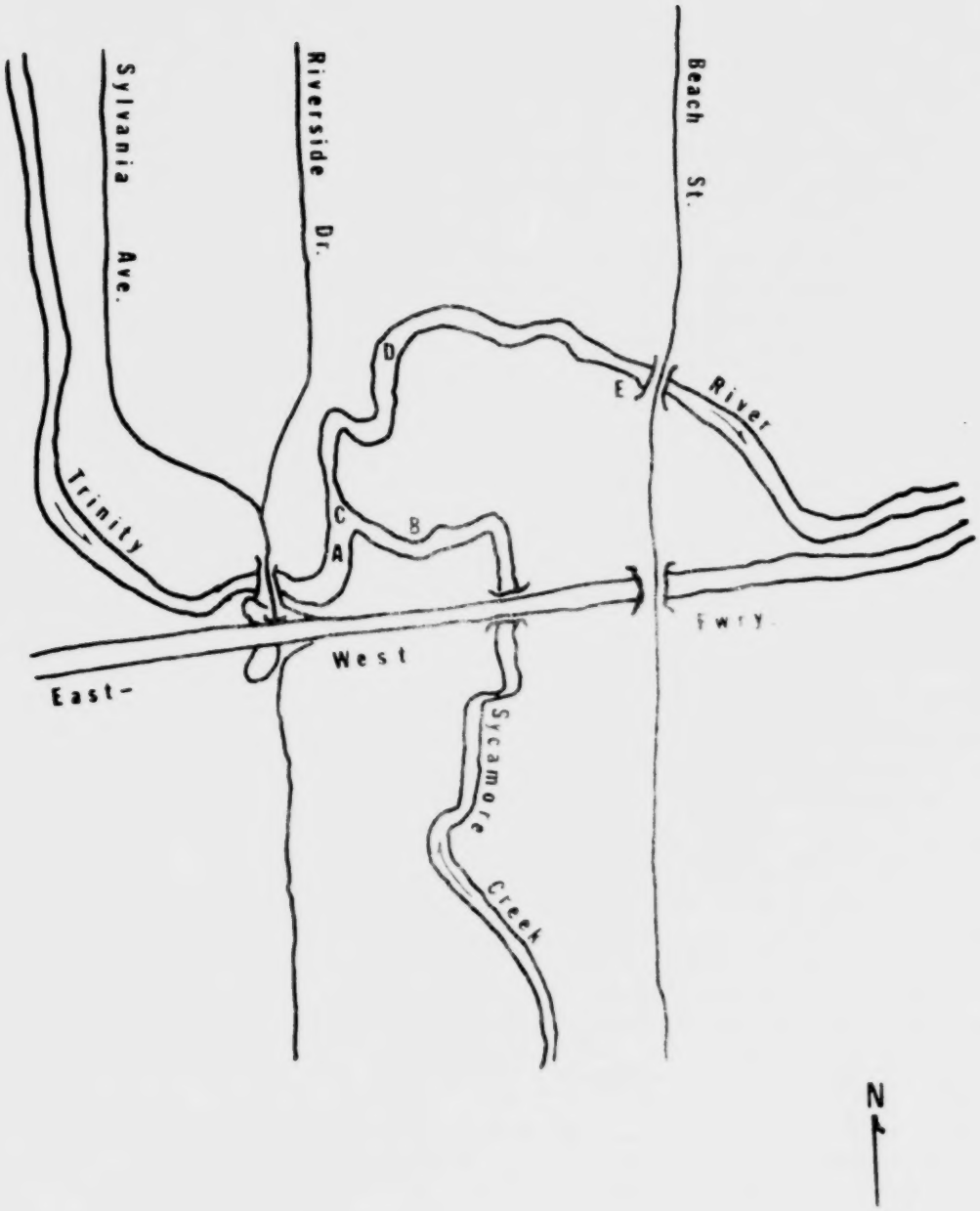


Figure 9. Map of Station X showing substations.
Scale: 1 inch = 2,000 feet.

Water samples were initially collected in 1 gallon, wide mouth jars. Samples were taken in midstream at approximately half the distance between surface and bottom, except where high water necessitated collection nearer one bank.

When the samples arrived in the laboratory, they were each shaken well, a portion was taken from each for immediate analysis and the rest was stored at 4°C until needed for further analysis.

Water temperature was taken by using either a mercury thermometer in shallow water or a Yellow Springs Instruments Hydrothermometer standardized against a mercury thermometer in deeper water. All readings were reported as degrees centigrade. Temperature was the only parameter measured directly while in the field.

Dissolved oxygen samples were taken by using standard BOD bottles which were filled at the river by using a hand barrel pump when possible. Bottles were overflowed approximately three volumes and care was taken to prevent entrapment of air bubbles. The method used in analysis for dissolved oxygen was a sulfamic acid Alsterberg modification of the Winkler method (Standard Methods for the Examination of Water and Wastewater, 12th Edition, 1965).

Determination of pH values were made in the laboratory using a calomel glass electrode, a Sargent-Welch or a Beckman Zeromatic pH meter.

Alkalinity measurements (phenolphthalein and methyl orange) were made in accord with Standard Methods for the Examination of Water and Wastewater, 12th Edition, 1965 and expressed as mg/l of $CaCO_3$.

The procedures for BOD (biochemical oxygen demand) determination were those in Standard Methods for the Examination of Water and Wastewater, 12th Edition, 1965. Some samples, due to their high oxygen demand, were diluted to 1/2 and 1/4 with downstream water from Substation E. Station V required special dilution water because the oxygen demand of the downstream water was too high. Dilution water was made according to the procedures in Standard Methods for the Examination of Water and Wastewater, 12th Edition, 1965. In the case of the sewage treatment plant effluent, the BOD samples were diluted to 1/10 and 1/50.

Chemical oxygen demand (COD) was determined using the method proposed by Standard Methods for the Examination of Water and Wastewater, 12th Edition, 1965. The equipment used was 250 milliliter erlenmeyer flasks with ground glass 24/40 necks and 300 mm jacketed or equivalent condensers and hotplates.

The Brucine method was used for analysis of nitrates (Standard Methods for the Examination of Water and Wastewater, 12th Edition, 1965). Each series of samples were accompanied by standards and a control blank. The results were recorded in mg/l NO_3-N. This value was converted to mg/l NO_3 by multiplying the value for mg/l NO_3-N by 4.43.

Orthophosphates and hydrolyzable phosphates were both determined using the method prescribed by the Federal Water Pollution Control Administration's publication, "FWPCA Methods for Chemical Analysis of Water and Wastes", November 1969. Samples were analyzed as quickly as possible after returning them to the laboratory.

Analysis for Ca, Mg, Cu, Zn and Fe followed those methods set forth by "FWPCA Methods". This was accomplished by filtering 250 milliliters of each sample through a 0.45 micron membrane filter. To the 250 milliliters of sample 0.75 milliliters of 1:1 HNO_3 was added. The 1:1 HNO_3 was made with demineralized water, using an ion exchange column. Each sample was then analyzed for the individual elements Ca, Mg, Cu, Zn and Fe. A Perkin-Elmer 303 Atomic Absorption Spectrophotometer was used, using a Texas Instruments chart recorder, a Boling three slot burner, and an air-acetylene flame. A standard curve was prepared everyday for each element before each series of samples were analyzed.

Per cent organics were determined for Stations I and III because of the high suspended solids content found in these effluents. The filter used in the analysis for Ca, Mg, Cu, Zn and Fe, was carefully oven dried at 102°C for several hours. The thick residue on each filter was carefully scraped into a pre-weighed combustion boat. This boat was put into a Sargent combustion apparatus using anhydrone and ascarite for collection of water and CO_2 respectively. A flow of about 90 bubbles per minute of compressed oxygen was passed through the combustion tube. The temperature of the combustion apparatus was approximately 625°C for the stationary element and about 700°C for the chain driven element. Per cent carbon was determined by multiplying the weight gain of the ascarite by the decimal fraction of carbon in CO_2.

Benthos

Effects of effluents on the benthic invertebrate populations were studied at seven areas along the Trinity River. Samples were obtained with a 1/25 M^2 VanVeen grab sampler. One pint aliquots were taken from the top of the grab making sure to get the surface down to several inches. This allowed for more samples to be taken since the amount of space required and the washing time for each sample was reduced considerably. Taking samples in this manner also helped reduce error resulting from variations in depth of the grab bite.

Ten samples were taken along each of four transects. Sample 1 was taken on the side of the river nearest the outfall while number 10 was near the opposite bank. Transects were located 25 yards upstream from the mouth of the outfall; at the mouth; and approximately 30-70 yards and 150-600 yards downstream from the outfall. The maximum depth of penetration of the benthos was measured by core sampling.

Samples were preserved in 10 per cent neutralized formalin and later washed through a .25 mm standard mesh screen #60. The animals were preserved in 70 per cent alcohol and identified to taxa.

Since benthos in this study were used primarily as monitors for toxic materials, specific identification was not deemed necessary. When pollution is heavy, whole taxonomic groups rather than individual species are affected (Hynes 1960).

Taxonomic resources included: Chu (1949), Eddy and Hodson (1961), Pennak (1953), Edmondson (1959) and Stephenson (1930).

Station Identification

Station	Description
I	Outfall from a railroad equipment cleaning area
II	Typical storm sewer receiving some effluent from small industrial plants and some untreated sewage
III	Chemical plant producing cracking catalysts for processing combustion engine fuels
IX	Chemical plant producing various types of acids
V	Sewage treatment plant receiving industrial and domestic wastes (trickling-filter type)
VI	Plant primarily engaged in metal etching using various acids
VII	Sewage treatment plant in a poor state of repair (Imhoff-lagoon)
VIII	Fuel oil and gasoline bulk loading station
IX	Small tributary receiving effluents from meat packing and rendering plants
X	Tributary receiving effluents from various small industries and a food packing plant

SECTION V

OBSERVATIONS

Bioassay

Station 1: Railroad Equipment Cleaning Area

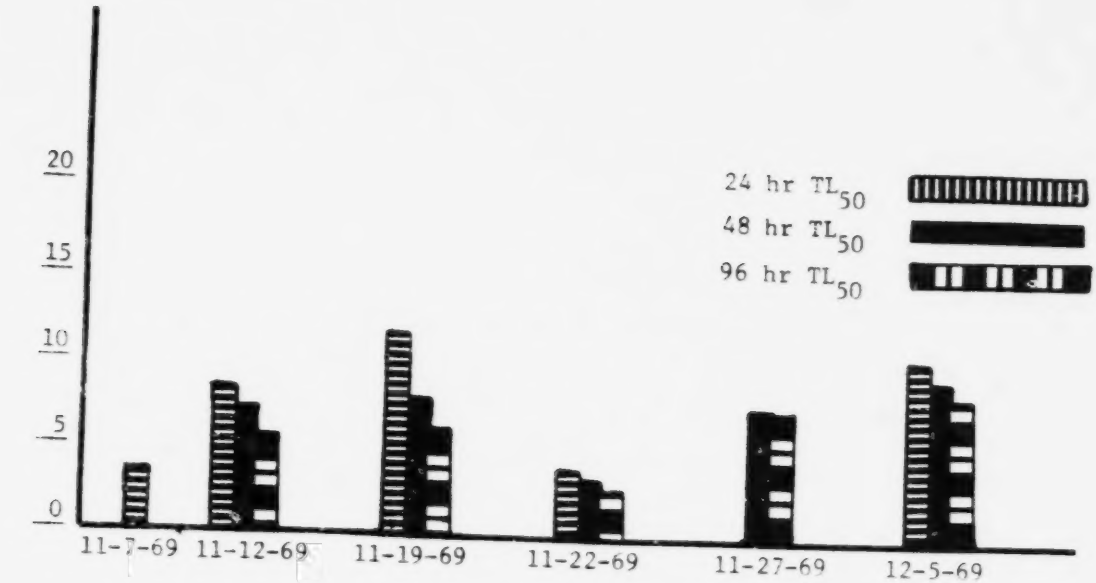
Effluent from a railroad equipment cleaning area was selected for initial testing. This station is the farthest upst' am (Trinity River) that was studied. Discharge of effluent was not continuous but on an intermittent basis. Fluid is released during the day and varies from a slight trickle or no flow at all to approximately 3 gallons per second. Quality of the fluid varied from time to time. Detergents, fuel oils and grease were among the primary constituents of the effluent. Other characteristics are listed in Table 1.

Table 1. Ranges for various parameters of Station I effluent.

Effluent	Range
Dissolved oxygen	2 - 9.4 ppm
Free carbon dioxide	0
Ph-th alkalinity	490 - 572 ppm
M.O. alkalinity	200 - 280 ppm
pH	10.1 - 11.5
Turbidity	50 - 55 JTU
Conductivity	1,500 - 2,400 micromhos/cm
Total seston	73.95 mg/1 - 185.5 mg/1
Bioseston	20.87 mg/1 - 48.75 mg/1
Abioseston	53.07 mg/1 - 136.75 mg/1
Dissolved solids	786.75 mg/1 - 1.483 g/1

Like other qualities of this effluent TL_{50} values varied. Several tests were conducted involving a variety of test organisms in order to establish a TL_{50} range. Table 2 and Figure 10 show the results of the various tests.

In early stages of the study it was found that effluent stored in the laboratory at room temperature for as long as five days increased in toxicity. This was demonstrated through successive tests using N. crysoleucas as test organisms. A satisfactory explanation has not been established. The increase in toxicity may be accounted for in part by the length of time effluent was held in detention pools in the railroad yard before being released. Similar successive tests were



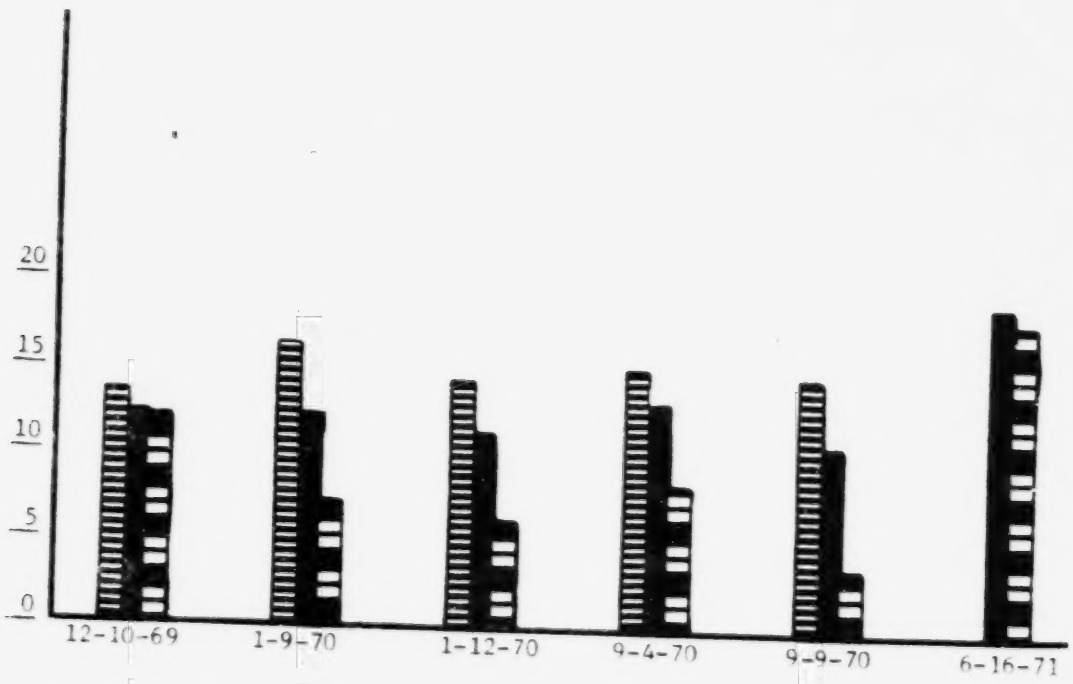


Figure 10. TL_{50} values for Station I effluents using golden shiners (Notemigonus crysoleucas (Mitchill)) as test organisms.

Table 2. TL_{50} values in per cent for Station I effluent.

Date	24 hrs	48 hrs	96 hrs	Test Organism	Av.Wt.G.
11-7-69	3.0			N. crysoleucas	2.1
11-12-69	8.0	7.0	6.0	N. crysoleucas	2.1
11-19-69	12.0	7.6	6.0	N. crysoleucas	1.98
11-22-69	3.4	3.0	2.5	N. crysoleucas	2.0
11-27-69	*	7.5	7.5	N. crysoleucas	2.1
12-5-69	10.4	9.0	8.0	N. crysoleucas	2.2
12-10-69	13.0	12.0	11.5	N. crysoleucas	2.2
1-9-70	16.0	12.0	7.0	N. crysoleucas	2.0
1-12-70	14.0	11.0	6.0	N. crysoleucas	2.1
9-4-70	14.4	12.5	8.0	N. crysoleucas	2.2
9-9-70	14.5	10.5	3.4	N. crysoleucas	2.0
6-16-70	*	18.0	18.0	N. crysoleucas	1.9
6-16-70	*	20.0	18.5	N. crysoleucas	1.9
3-13-70	18.0	17.0	15.5	P. promelas	2.1
3-13-70	14.0	14.0	14.0	P. promelas	2.1
3-18-70	16.0	15.0	14.0	P. promelas	1.98
3-18-70	15.0	12.2	11.4	P. promelas	1.98
3-24-70	16.0	15.0	8.0	P. promelas	2.1
6-22-70	11.5	10.5	9.2	M. salmoides	1.4
6-22-70	11.5	10.75	6.5	M. salmoides	1.4
8-17-70	4.4	3.5	2.5	I. punctatus	0.53
	5.5	4.6	3.3	I. punctatus	0.53

*No mortality

conducted but a marked increase in toxicity was not detected. Pimephales promelas as well as N. crysoleucas were used as test organisms. It was observed that P. promelas was more tolerant to the effluent than N. crysoleucas.

Although Station I effluents vary in quality from time to time, the TL_{50} value is relatively consistent. The TL_{50} does range between 2.5% and 18.5% for 96 hours but of the 22 tests conducted, only seven values for 96 hours were above 10.0% (Table 2).

Heavy foaming accompanied the effluent because of its content of detergent plus agitation as it was being discharged. The foam covered a large area of the river in the vicinity of the outfall and extended a considerable distance downstream. The presence of the foam is normally considered to impair uptake of oxygen by the water and reduce light penetration which in turn reduces photosynthesis and release of oxygen. The toxic quality of the effluent combined with the insulating effect of its foam result in definite undesirable effects on the biota of the surrounding environment.

Station II: Typical Storm Sewer Receiving Effluent from Small Industrial Plants and Some Untreated Sewage

Station II outfall is located approximately 1 mile downstream from Station I. Effluent from this outfall contained a variety of substances including untreated sewage and nontoxic substances. The pH ranged between 7.1 and 7.5, dissolved oxygen 3.0 - 7.0 ppm and conductivity not over 750 micromhos per centimeter. The TL_{50} values are listed in Table 3.

Table 3. TL_{50} values in per cent for Station II effluent.

Date	24 hrs	48 hrs	96 hrs	Test Organism	Av.Wt.G.
9-26-70	42	42	42	N. crysoleucas	2.2
9-26-70	42	42	42	N. crysoleucas	2.1
9-29-70	42	42	42	I. punctatus	2.0
9-29-70	42	42	42	I. punctatus	
9-30-70	*	*	*	I. punctatus	2.1
9-30-70	*	*	*	I. punctatus	2.1

*No mortality

The test organisms, N. crysoleucas, did not survive more than 2 hours in the 100% and 50% concentrations, but there was 100% survival in all other concentrations. Using effluent from the same collection and I. punctatus as test organisms, the test was repeated with identical results. It was found that by aerating the 100% and 50% solutions for 1 hour before exposure both I. punctatus and N. crysoleucas survived in all concentrations throughout the 96-hour test period. This observation indicated that the mortality in previous tests was probably due to lack of oxygen. The effluent appeared to have a high content of raw sewage from some place and the rapid decomposition of organic material was considered to account for the low dissolved oxygen. Subsequent tests of the effluent from this outfall resulted in no mortality of the test organisms in 100% or lower concentrations, even though none of the concentrations were aerated. It seems apparent that the most undesirable quality of the Station II effluent is the raw sewage that is present from time to time. Decomposition of the organic matter could reduce the oxygen supply and effect an extensive environmental stress on the fauna.

Station III: Chemical Plant Producing Cracking Catalysts for Processing Combustion Engine Fuels

Station III is approximately 2 miles downstream from Station II. Effluent is discharged through a tile sewer approximately 20 inches

in diameter into a pool approximately 20 yards from the edge of the Trinity River when it is at its normal level. It flows freely from the pool into the river. During periods of excessive rain this outfall is obscured by high water. The flow of effluent is intermittent and, at times, may fill the tile sewer to a depth of 10 - 12 inches. A valid estimate of peak flow in cubic feet per second was not ascertained because of the volume and force of the flow.

The effluent contains a white floc which usually gives it a milky color, although at times it may take on an aqua or orange tint (Figure 11). The floc settles rapidly and is deposited in great quantities in the area of the pool. An extensive plume caused by the floc may be seen in the Trinity River (Figure 12). Other characteristics of the effluents are listed in Table 4.

Table 4. Ranges for various parameters of Station III effluent.

Effluent	Range
Dissolved oxygen	4.9 - 10.3 ppm
Free carbon dioxide	0
Ph-th alkalinity	0.00 - 1,480 ppm
M.O. alkalinity	3.4 - 2,046.0 ppm
pH	1.5 - 11.9
Turbidity	36 - 95 JTU
Conductivity	1,150 - 8,000 micromhos/cm
Total seston	9.1 - 556.1 mg/l
Bioseston	2.1 - 116.3 mg/l
Abioseston	28.8 - 434.7 mg/l
Dissolved solids	194.5 - 8,835.0 mg/l

Variations in pH as well as color prompted a continuous monitoring of the station throughout a working day. Parameters monitored and their values are listed in Table 5.

The TL_{50} values for Station III were rather varied. Table 6, Figure 13 and Figure 14 show the various test results.

Gills of each of the dead test organisms were examined and found to be coated with a heavy layer of the white floc from the effluent. This floc, imbedded in mucus, was of such copious supply that each operculum was greatly distended. This suggested a possible physical effect on the fish. Tests were repeated using fluid without the floc. The TL_{50} for fluid containing the floc was 24.0% for 24 hours, 12.5% for 48 hours and 7.0% for 96 hours. Using only the supernatant, the TL_{50} was 41.0% for 24 hours, 38.5% for 48 hours and 34.5% for 96 hours. The test organism used was P. promelas. Since effluents for the two tests

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Figure 11. Station III outfall evidencing white floc in effluent.

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Figure 12. Plume in the Trinity River caused by floc in Station III effluent.

Table 5. Parameters of Station III monitored throughout a 7-hour period.

Time of Surge	pH	Temperature Centigrade	Specific Conductivity	Dissolved Oxygen
8:55	7.5	25°	2,050	6.15
9:10	5.8	26°	2,050	5.7
9:26	6.2	25.5°	1,600	5.7
9:43	1.9	25°	++8,000	5.8
9:57	3.0	24°	+8,000	5.6
10:12	4.5	25°	4,000	5.8
10:25	6.2	26°	3,750	5.7
10:41	6.5	26°	3,250	5.6
10:57	6.4	23.5°	3,000	6.0
11:11	6.6	22°	2,250	6.0
11:25	6.5	22°	2,200	6.1
11:40	3.3	23.5°	+8,000	5.9
11:53	1.8	23.5°	++8,000	5.7
12:07	3.35	28°	6,500	5.2
12:21	4.4	28°	3,750	5.2
12:34	5.7	28°	4,500	5.2
12:48	6.1	28°	3,500	5.2
1:02	6.3	26°	3,000	5.5
1:17	5.9	23.5°	2,500	5.7
1:31	6.1	23°	4,000	5.7
1:44	2.25	23°	++8,000	5.7
1:58	2.8	28°	+8,000	5.1
2:12	4.5	28.5°	4,000	5.1
2:28	6.35	29°	3,500	4.9
2:48	6.1	26°	3,250	5.4
3:00	2.5	24.5°	+8,000	5.6
3:13	2.1	25°	++8,000	5.5
3:27	2.8	27°	5,500	5.3
3:47	5.7	30°	5,500	5.0
4:00	6.6	29°	8,000	5.1

+ = Greater than

++ = Much greater than

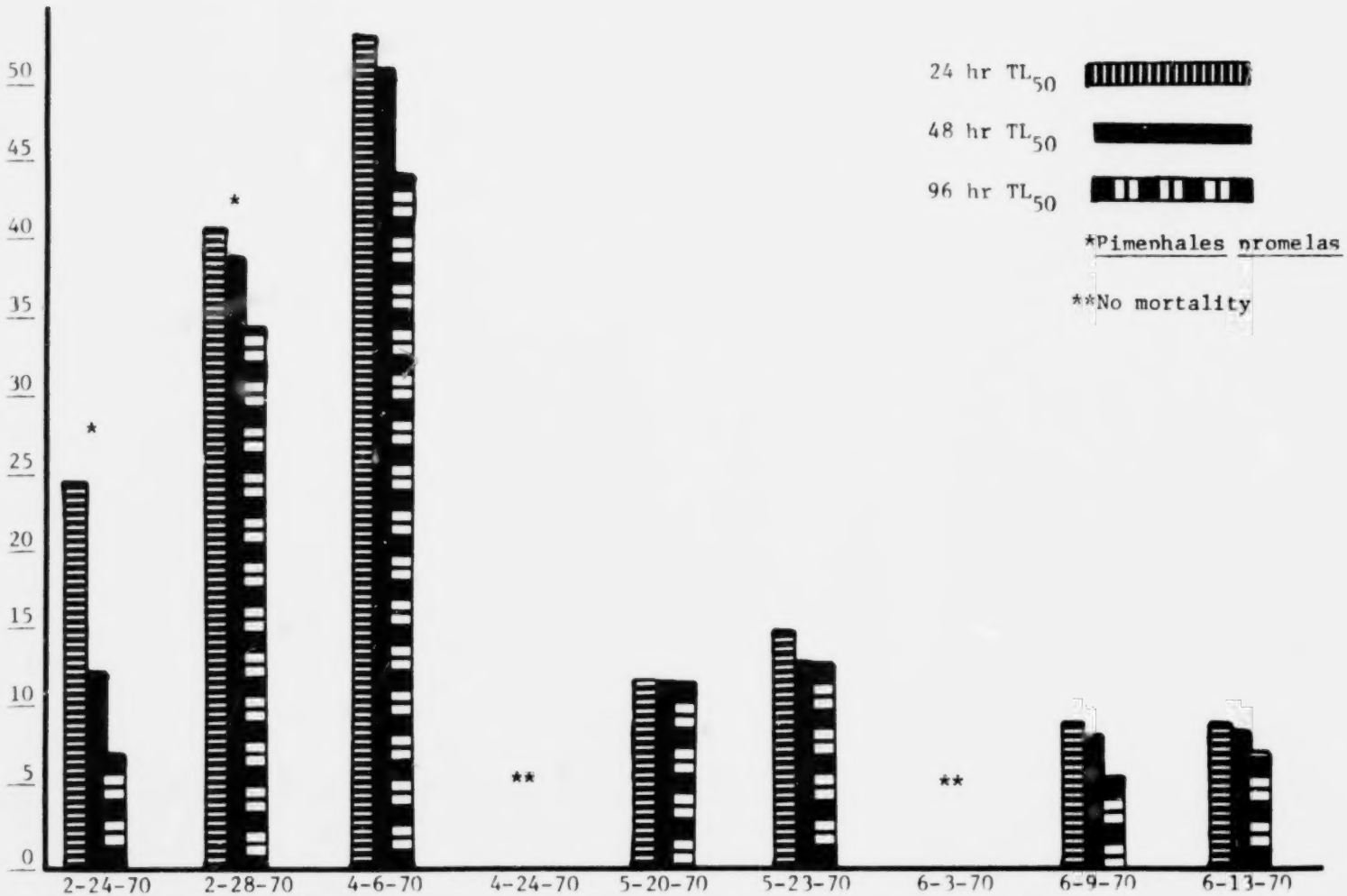

Figure 13. TL_{50} values for Station III effluent using golden shiners (Notemigonus crysoleucas (Mitchill)) and fathead minnows (Pimephales promelas Rafinesque) as test organisms.

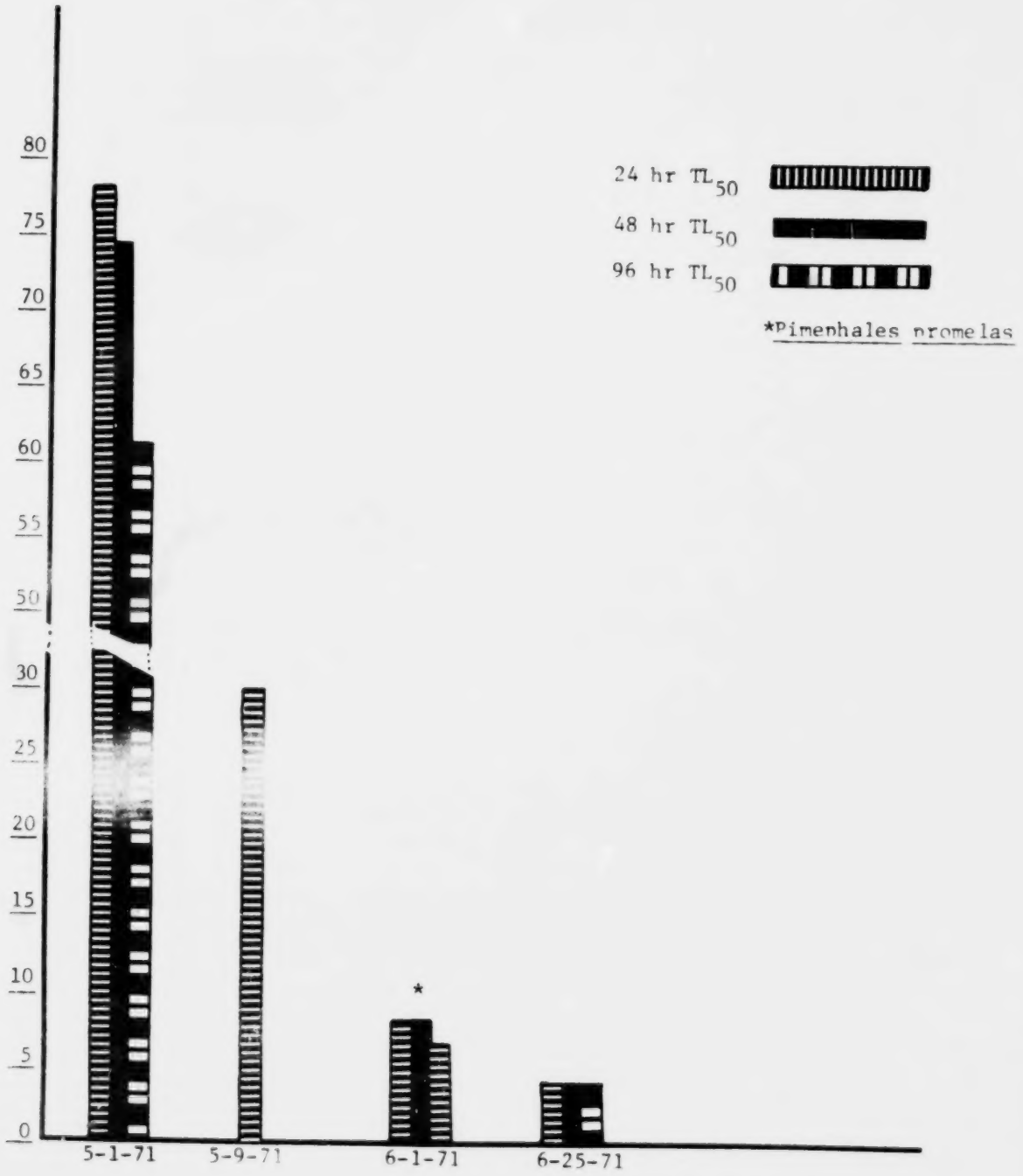

Figure 14. TL_{50} values for Station III effluent using golden shiners (Notemigonus crysoleucas (Mitchill)) and fathead minnows (Pimephales promelas Rafinesque) as test organisms.

Table 6. TL_{50} values in per cent for Station III.

Date	24 hrs	48 hrs	96 hrs	Test Organism	Av.Wt.G.
2-24-70	24.0	12.5	7.0	P. promelas	2.0
2-28-70	40.0	39.0	39.0	P. promelas	2.0
2-28-70	42.0	38.0	30.0	P. promelas	2.0
4-6-70	53.2	51.0	45.0	N. crysoleucas	2.2
4-24-70	*	*	*	N. crysoleucas	2.1
5-20-70	12.0	12.0	12.0	N. crysoleucas	2.2
5-23-70	10.0	10.0	10.0	N. crysoleucas	2.2
5-23-70	21.0	16.0	16.0	N. crysoleucas	2.2
6-3-70	*	*	*	N. crysoleucas	2.3
6-9-70	9.3	8.7	6.2	N. crysoleucas	2.0
6-9-70	9.3	8.6	5.6	N. crysoleucas	2.0
6-13-70	9.7	9.7	8.6	N. crysoleucas	2.2
6-13-70	9.0	8.7	6.6	N. crysoleucas	2.2
5-1-71	78.0	74.0	56.0	N. crysoleucas	2.2
5-1-71	78.0	74.0	56.0	N. crysoleucas	2.2
5-9-71	30.0	30.0	30.0	N. crysoleucas	2.8
6-1-71	8.0	8.0	6.5	P. promelas	2.3
6-1-71	7.2	7.0	6.5	P. promelas	2.3
6-25-71	3.3	3.3	3.3	N. crysoleucas	2.1
6-25-71	3.3	3.3	3.3	N. crysoleucas	2.1

*No mortality

were collected at different times and since quality of the effluent varied as reflected in Table 5, this and successive tests did not prove conclusively that physical effects of the floc accounted for the low TL_{50} values.

Gills of fish exposed to Station III effluent were examined grossly and compared with gills of fish not exposed to the effluent. It was observed that considerable gill tissue was eroded away after relatively short periods of exposure in all concentrations (Figure 15). Injury to the gill membrane probably contributed to early death of some of the test organisms.

Station III fluid was stored in the laboratory and successive tests were conducted in an attempt to determine an increase or decrease in toxicity with age. On the tests using N. crysoleucas as test organisms, it was observed that there was not more than 1.0% variation in TL_{50} values for 24, 48 and 96 hours, indicating that this particular collection of fluid was quite stable. However, variability in TL_{50} values in previous tests plus differences in quality of the fluid (Table 6) prohibit a conclusive statement about consistent stability of Station III effluent. The variation in percentage for TL_{50} determinations is shown in Table 7.

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Figure 15. Gills taken from Notemigonus crysoleucas.

A. Gills taken from control--not exposed to Station III effluent.

B. Gills taken from fish after exposure for 15 minutes to a 100% concentration of Station III effluent.

Table 7. TL_{50} value ranges for Station III effluent.

Time interval in hours	24	48	96
High %	78.0	74.0	65.0
Low %	3.3	3.3	3.3

Station III effluents varied extremely in quality as reflected in Tables 5 and 6 and Figures 13 and 14. The pH and TL_{50} values were the parameters most diverse in value. The cycling effect as indicated in Table 5 accounted for the diversity in TL_{50}. When collecting the effluent there was no way of telling what the stage of processing was. While collecting sufficient fluid for a bioassay (150 - 175 gallons) several surges occurred and pH frequently varied in the individual containers. In an attempt to avoid great variation in quality of effluent, no fluid was collected at the very start or very end of a surge. However, quality of the fluid might vary from cycle to cycle.

The presence of the floc was very obvious as shown in Figures 11 and 12. The material greatly altered the environment in the vicinity of the pool and the left bank of the river looking downstream. It had a detrimental effect on the fish. On March 25, 1970, a rather extensive fish kill was observed in the vicinity of the outfall. As a result of high water, several gizzard shad (Dorosoma cepedianum (LeSueur)) and river carpsuckers (Carpiodes carpio (Rafinesque)) were apparently trapped in the pool into which the effluent was discharged. The fish were in such a state of decomposition when discovered that an autopsy was inconclusive. At times fish were observed floating lifelessly on their backs in currents of Station III effluent.

On July 1, 1971, this chemical company completed its installation of equipment to reclaim some of the material being discharged into the Trinity River. Also, their effluent was diverted to the sanitary sewer and directed through the Fort Worth Sewage Treatment Plant. A sample of the effluent after it passed through the clarifiers and released into the large holding pools was tested. There was no mortality in the undiluted fluid. The system installed accounted for a better quality of effluent. The area of the Trinity River into which the effluent had been discharged originally has cleared considerably. The presence of the floc plume in the river is no longer apparent. Much of the deposit of floc except in the more isolated area of the pool has been scoured from the region by the current of the river

Station IV: Chemical Plant Producing Various Types of Acids

Effluent from Station IV is buffered through an automatic system and then released into a drainage ditch which leads to the Trinity River. Three successive tests in duplicate were run on this effluent. Effluent for the first test was collected from the discharge unit next to the plant immediately after passing through the buffering system. The pH of the material was 8.7. All test organisms survived throughout 96 hours at 100% and all other concentrations. Effluent for the second test was collected four days later and approximately 75 yards from the buffering system. The TL_{50} value for 24 hours was not determined but it was 32.0% for 48 and 96 hours. The pH of this fluid was 2.6. This indicated a malfunctioning of the buffering system which was verified by one of the company officials. A third test was conducted and all of the test organisms survived throughout the 96 hours in all concentrations, as in the first test. The pH of the effluent was 8.7. Channel catfish were used in all tests. Results of work on effluent from this industry are shown in Table 8.

Table 8. TL_{50} values in per cent for Station IV.

Date	24 hrs	48 hrs	96 hrs	Test Organism	Av.Wt.G.
11-16-70	*	*	*	I. punctatus	11.2
11-16-70	*	*	*	I. punctatus	11.2
11-20-70	*	32	32	I. punctatus	11.1
11-20-70	*	32	32	I. punctatus	11.1
11-24-70	*	*	*	I. punctatus	11.1

*No mortality

Based on these tests and using I. punctatus as test organisms, it appears that the buffering system, when functioning properly, is effective so far as quality of effluent is concerned. It may be deduced, however, that the effluent should be kept under constant surveillance, and should receive immediate attention with the slightest indication of malfunctioning of the buffering system.

Station V: Sewage Treatment Plant Receiving Industrial and Domestic Wastes

Station V is located approximately 3 miles downstream from Station III. An average of approximately 30,000,000 gallons of effluent per day is discharged through two outlets into the Trinity River. Fluid going into the plant as well as that leaving the plant was tested. It was necessary to aerate the dilution water because of the low dissolved

oxygen content of the fluids entering the plant. Tests were run in duplicate using hybrid sunfish (longear - green sunfish) and I. punctatus. There was no mortality in undiluted effluent from the outlets. There was mortality in the effluent going into the plant. The TL_{50} values for the above effluents are listed in Table 9 and other characteristics are listed in Table 10.

Table 9. TL_{50} values in per cent for Station V.

Date	24 hrs	48 hrs	96 hrs	Test Organism	Av.Wt.G.
Outlet					
10-16-70	*	*	*	Hybrid sunfish	2.3
10-16-70	*	*	*	Hybrid sunfish	2.3
10-21-70	*	*	*	I. punctatus	2.3
10-21-70	*	*	*	I. punctatus	2.3
Inlet					
10-16-70	15.0	12.7	10.5	I. punctatus	2.2
10-16-70	21.75	18.0	17.0	I. punctatus	2.2
11-3-70	13.5	10.5	10.5	I. punctatus	18.5
11-3-70	13.5	10.5	10.5	I. punctatus	18.5

*No mortality

Table 10. Ranges or values for various parameters of Station V.

Parameter	Range/Value
Dissolved oxygen	0.8 - 6.1
pH	6.7 - 7.3
M.O. alkalinity	190 - 280 ppm
Turbidity	10 - 17 JTU
Conductivity	820 - 1,048 micromhos/cm
Total seston	146.7 mg/l (inlet)
Total seston	34.6 mg/l (south outlet)
Total seston	18.3 mg/l (north outlet)
Bioseston	91.5 mg/l (inlet)
Bioseston	23.2 mg/l (south outlet)
Bioseston	10.9 mg/l (north outlet)
Abioseston	55.2 mg/l (inlet)
Abioseston	11.4 mg/l (south outlet)
Abioseston	7.4 mg/l (north outlet)
Dissolved solids	7,350 mg/l (inlet)
Dissolved solids	6,535 mg/l (south outlet)
Dissolved solids	6,237 mg/l (north outlet)

There was an appreciable amount of foaming as a result of agitation plus detergents at each of the outlets. The foam persisted quite a distance downstream before it dissipated. It was quite evident that this factor had a deleterious effect on the fauna in the respective areas.

The effect of treatment of wastewater in the sewage treatment plant for the respective test organisms is reflected in Table 9. Although toxicity of fluid at both outlets for the fish was nil at the time they were exposed, quality of the effluent depends upon quality of the fluid coming into the plant. It is necessary at this time to withhold a positive statement indicating quality of effluent in the future. Industrial plants as in the case of the chemical plant producing cracking catalysts are gradually diverting their waste effluents to the sanitary sewer and through sewage treatment plants. This will have a definite influence on the quality of the effluent from the sewage treatment plant and possibly on bioassay results.

Station VI: Plant Primarily Engaged in Metal Etching Using Various Acids

Station VI is just east of the city limits of Fort Worth. This plant is somewhat removed from the Trinity River but a number of gravel pits close by are filled with the effluent which seeps through the soil to channels and may eventually get into the river. A survey of the premises and results of preliminary tests indicated that it would be advisable to select several substations for study in order to ascertain a better picture of the situation (Figure 16).

Substations A and B are located at two outfalls into a holding pool and Substation C is in the holding pool. Effluent from Substation D flows to Substation B. Since there was no difference in their qualities, Substation D was abandoned. Substation E is located below the holding pool and Substation F is in the gravel pit most directly connected with the holding pool and possibly most likely to overflow. Effluent from Substation E seeks its own course in a very diverse manner into the gravel pit some 150 yards from Substation E.

The pH of Station VI effluent varied at the respective substations as shown in Table 11.

Table 11. pH value ranges at the respective substations of Station VI.

Substation	A	B	C	E	F
Low	0.8	7.0	6.8	1.9	6.8
High	7.6	11.0	8.0	10.4	8.9

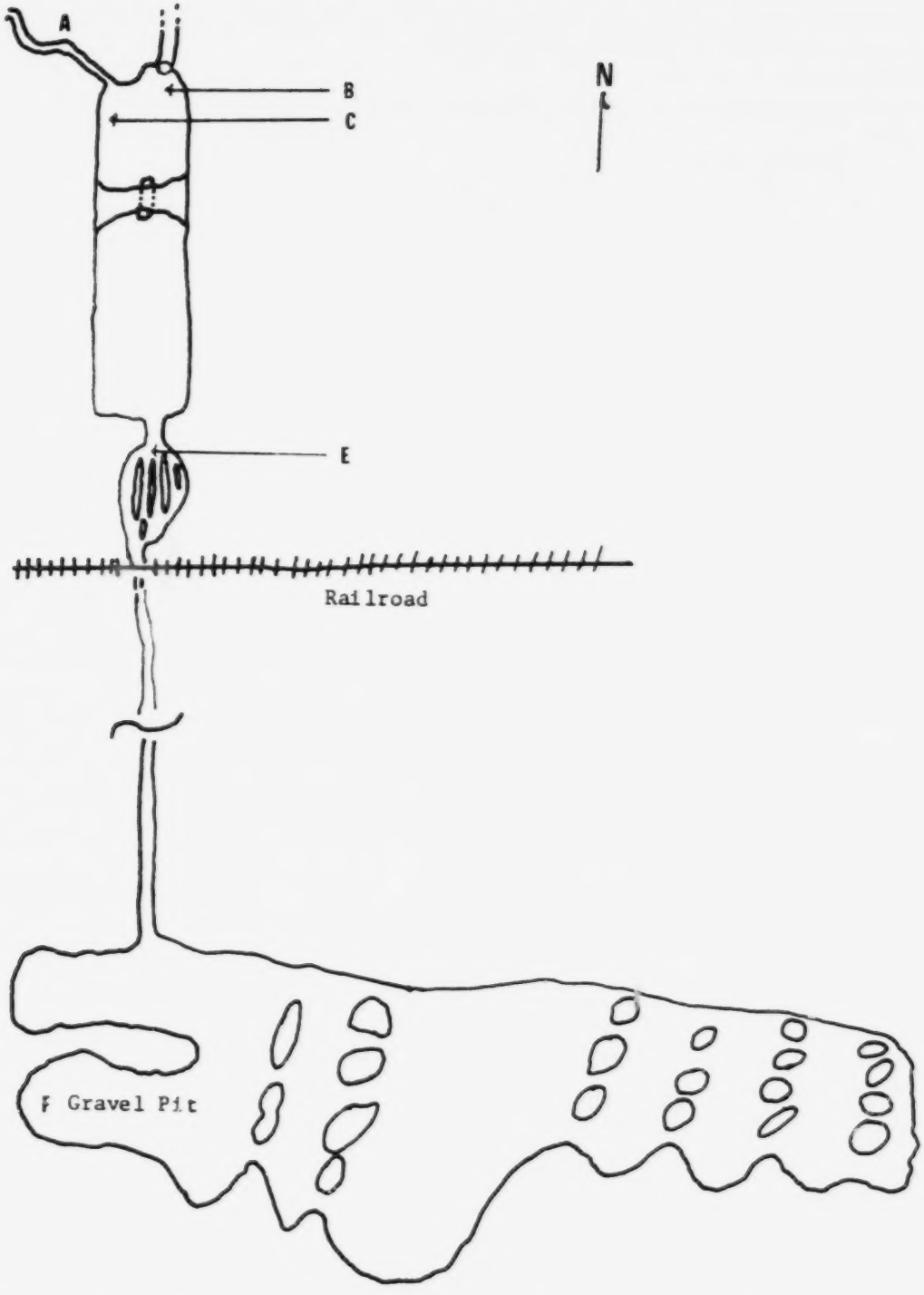

Figure 16. Map of Station VI study area showing substations. Substations are indicated by letters A, B, C, E and F.

Table 12. TL_{50} values in per cent for all substations of Station VI.

Date/Substation	24 hrs	48 hrs	96 hrs	Test Crganism	Av.Wt.G.
Substation A					
12-3-70	8.4	8.4	8.4	N. crysoleucas	2.0
12-3-70	8.4	8.4	8.4	N. crysoleucas	2.0
12-16-70	10.5	3.0	3.0	N. crysoleucas	2.4
12-16-70	10.0	3.75	3.75	N. crysoleucas	2.4
Substation B					
12-10-70	5.0	5.0	5.0	N. crysoleucas	2.1
5-25-71	23.5	22.5	21.0	P. promelas	1.8
5-25-71	34.5	28.0	28.0	P. promelas	1.8
Substation C					
1-5-71	*	*	*	N. crysoleucas	2.1
Substation E					
1-11-71	5.5	4.75	4.5	N. crysoleucas	2.0
1-17-71	5.4	5.4	5.4	N. crysoleucas	2.3
1-17-71	5.6	5.6	5.4	N. crysoleucas	2.3
1-23-71	31.5	31.5	31.5	N. crysoleucas	2.1
1-23-71	33.25	32.25	30.0	N. crysoleucas	2.1
2-6-71	*	*	*	N. crysoleucas	2.0
2-11-71	11.25	11.25	10.5	N. crysoleucas	2.2
2-11-71	15.0	10.75	10.75	N. crysoleucas	2.2
2-16-71	18.75	18.75	16.25	N. crysoleucas	2.1
2-16-71	15.0	14.0	12.0	N. crysoleucas	2.1
4-14-71	25.0	17.5	17.5	N. crysoleucas	2.1
4-14-71	17.5	17.5	14.0	N. crysoleucas	2.0
5-18-71	20.0	8.4	8.4	P. promelas	1.9
5-25-71	50.0	41.0	36.5	N. crysoleucas	1.9
Substation F					
3-10-71	56.0	56.0	56.0	N. crysoleucas	1.7
3-10-71	56.0	56.0	56.0	N. crysoleucas	1.7
3-25-71	75.0	70.0	#	N. crysoleucas	2.2
3-25-71	75.0	70.0	#	N. crysoleucas	2.1
4-1-71	*	90.0	90.0	N. crysoleucas	2.1
4-14-71	7.5	7.0	6.2	N. crysoleucas	2.6
4-14-71	7.5	5.5	5.5		
6-3-71	55.0	51.75	51.75	N. crysoleucas	2.2
6-3-71	55.0	55.0	55.0	P. promelas	2.2
6-10-71	73.0	73.0	73.0	P. promelas	2.1
6-10-71	75.0	71.0	69.0	P. promelas	2.1

*No mortality
#Total mortality

Eighteen tons of lime were dumped into the holding pool (Substation C) just prior to the first sampling of the area. This may have influenced the pH values at Substations C, E and F.

Effluent at Substation A comes from an area where materials are removed from an acid bath and washed. The pH varies according to the stage of the process and the amount of diluent water. In collecting 160 gallons of fluid from this substation the pH ranged between a low of 0.9 and a high of 3.0. Substation B fluids come from tanks in another area with a different type of processing from that of Substation A. Substation C effluent is a mixture of Substations A and B, each with quite diverse pH values. Substations C, E and F received the possible full effect of the lime; however, the low reading at Substation E does not so indicate (Table 11). Substation F received some fluid resulting from periodic washing of concrete mixing trucks from a nearby concrete mixing plant.

The TL_{50} values, like pH, varied at the respective substations and between substations. Fluids from Substations A and E were most toxic. Table 12 and Figures 17, 18 and 19 show the results of the bioassay.

Fish reacted very violently to some of the fluid collected. When exposed to full strength material, death frequently occurred within 30 seconds. Eyes bulged abnormally and there was a general contortion of the body. Tissues eroded away rapidly and when the fish were left in the fluid for 30 to 45 minutes, the viscera were exposed (Figure 20).

Conductivity was expectedly high at Substation A ranging between 2,200 and greater than 8,000 micromhos per centimeter. The effluents come from a part of the plant where metal etching is done. Conductivity values for all substations are listed in Table 13.

Table 13. Conductivity range in micromhos/cm for respective substations of Station VI.

Substation	A	B	C	E	F
Low	2,200	700	1,800	690	1,250
High	>8,000	2,200	2,200	>8,000	2,080

High toxicity of the Station VI effluent was usually associated with high conductivity. Effluent from Substation A was usually very turbid. Turbidity ranges for all substations are listed in Table 14.

High turbidity was usually associated with high conductivity of Station VI effluents. Suspended solids and dissolved solids of Station VI effluents varied considerably at each substation and from substation to substation. The same was true with dissolved solids. Ranges of seston and dissolved solids are listed in Table 15.

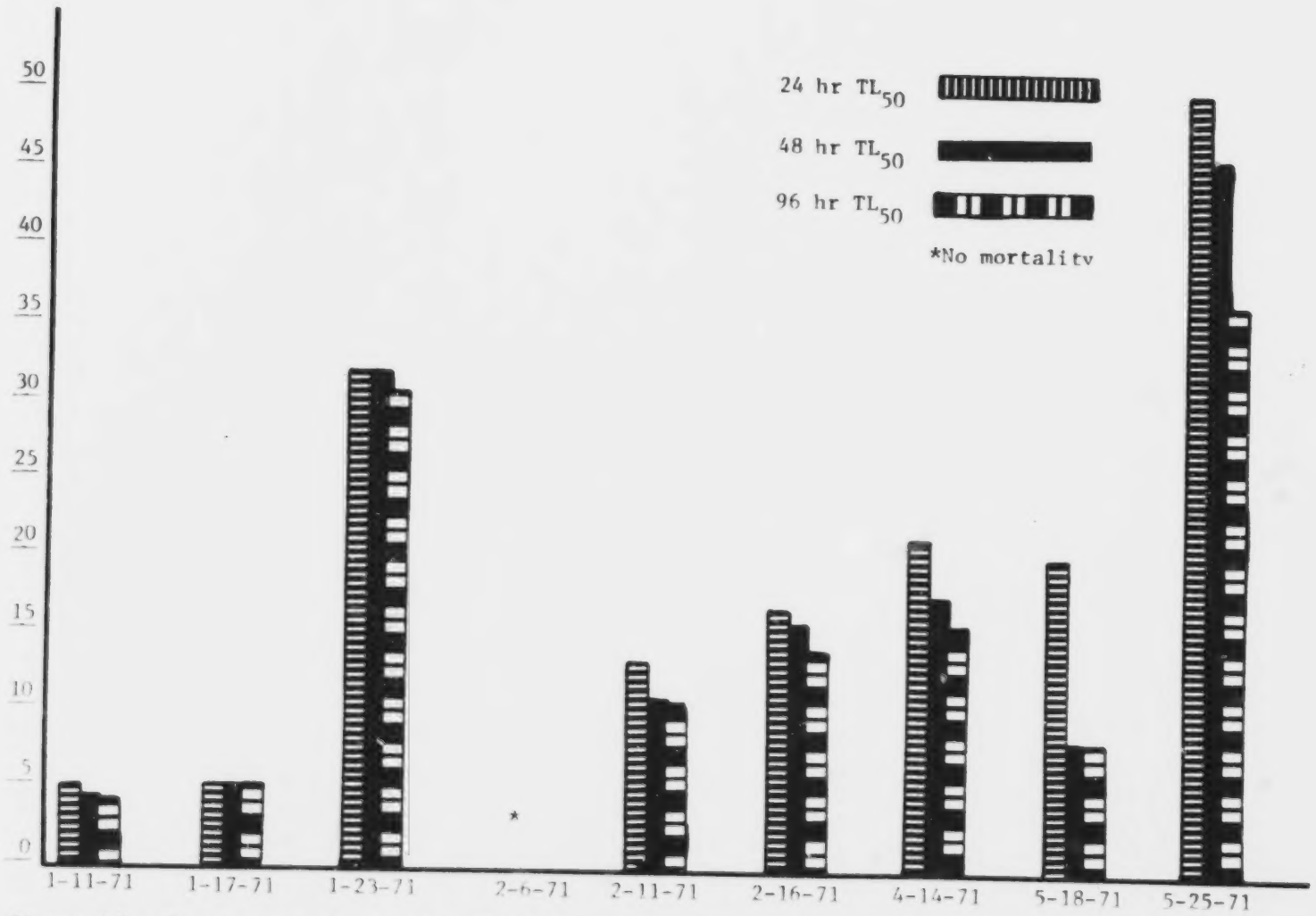

Figure 17. TL_{50} values for Station VI effluent using golden shiners (Notemigonus crysoleucas (Mitchill)) as test organisms. Substation E.

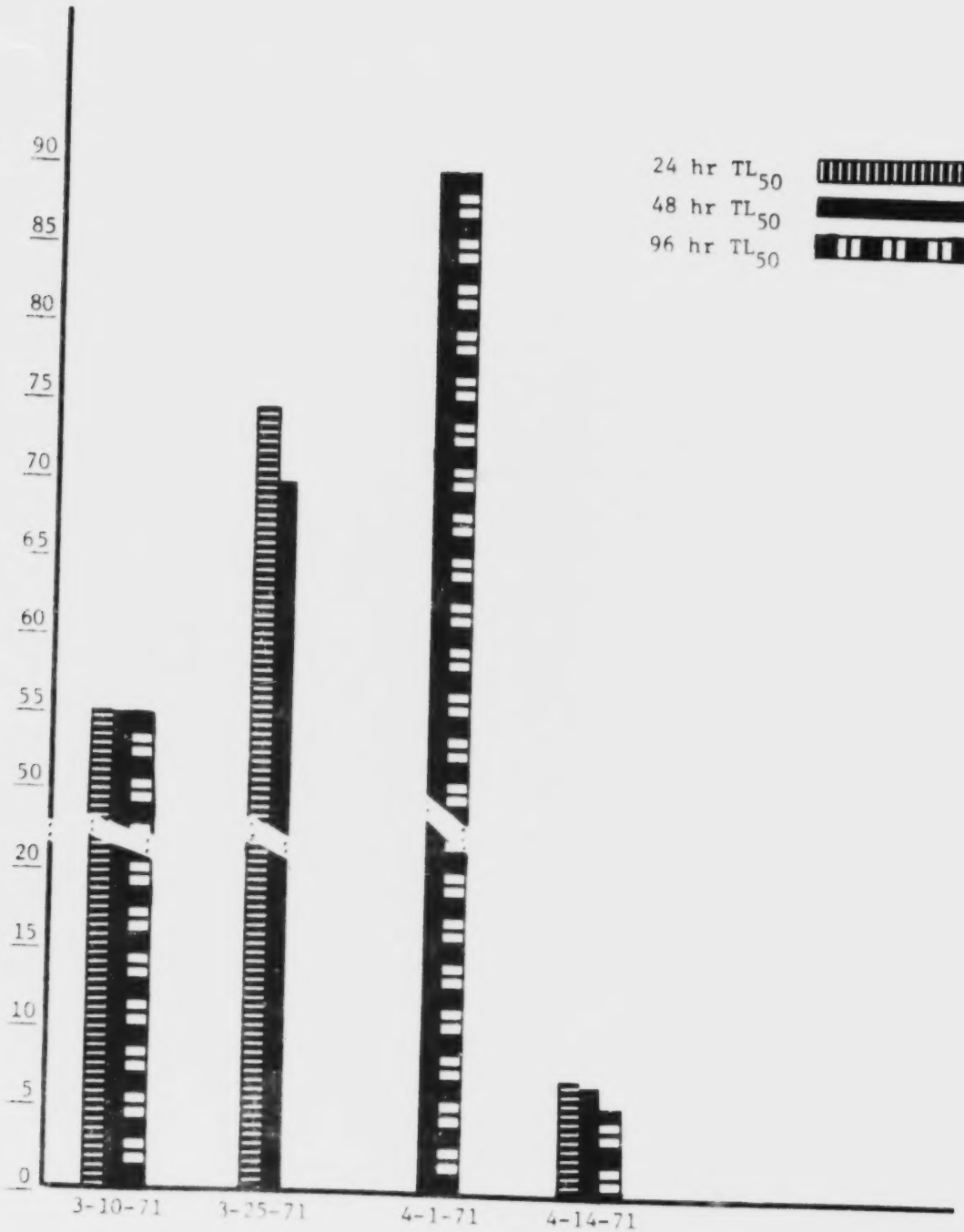

Figure 18. TL_{50} values for Station VI effluent using golden shiners (Notemigonus crysoleucas (Mitchill)) as test organisms. Substation F.

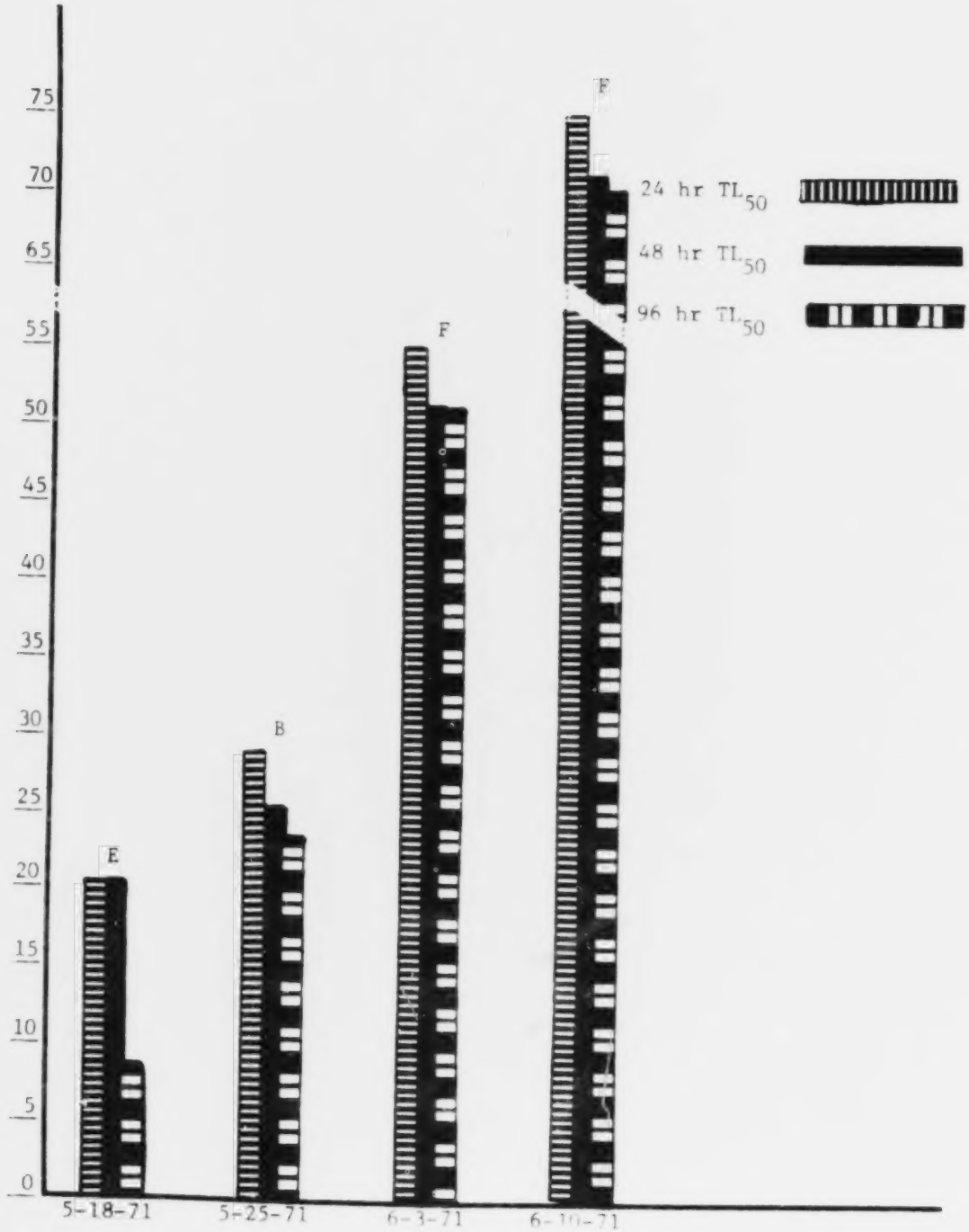

Figure 19. TL_{50} values for Station VI effluent using fathead minnows (Pimephales promelas Rafinesque) as test organisms. Substations are indicated by capital letters.

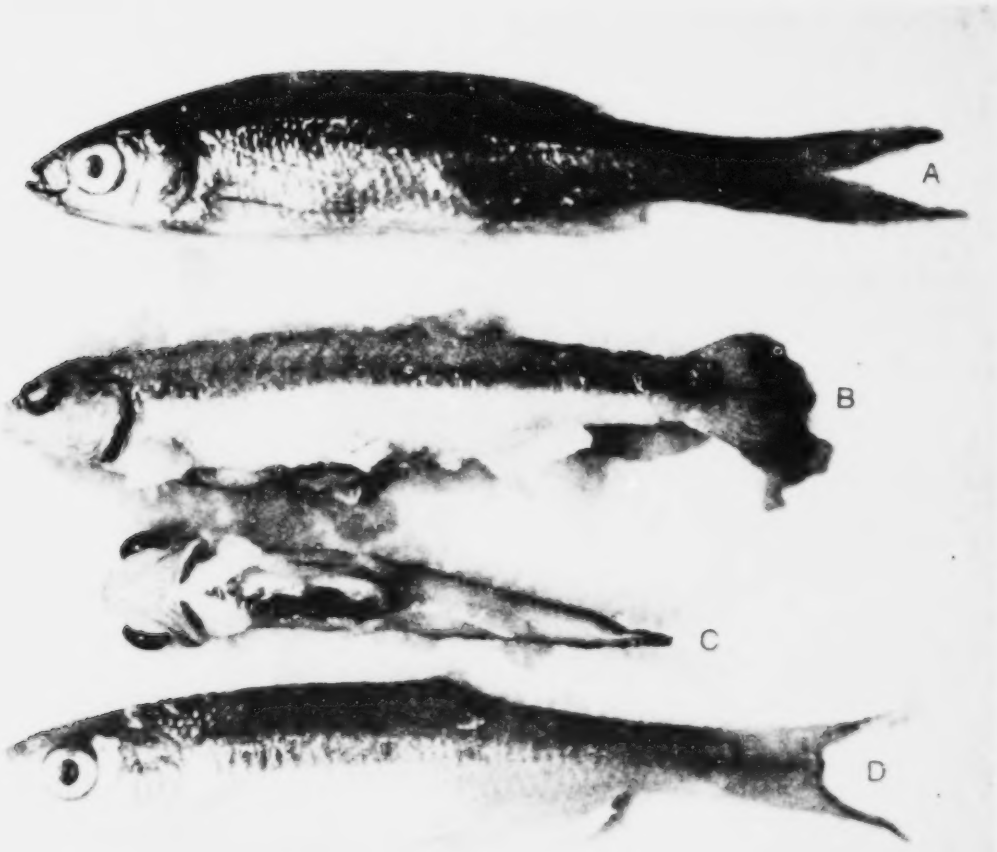

Figure 20. Notemigonus crysoleucas exposed to a 100% concentration of Station VI effluent.

A. Control--no exposure.

B and C. Exposed for 40 minutes to a 100% concentration showing erosion of fins and body tissue.

D. Exposed to a weaker solution showing erosion of tail and fins.

Table 14. Turbidity ranges expressed in Jackson Turbidity Units (JTU) for all Station VI substations.

Substation	A	B	C	E	F
Low	4	4	4	5	5
High	220	11	9	56	16

Table 15. Total seston, abioseston, bioseston and dissolved solids values in mg/l for Station VI.

Substation	Total Seston		Abioseston		Bioseston		Dissolved Solids	
	High	Low	High	Low	High	Low	High	Low
A	256.1	---	240.0	---	16.1	---	4,897.0	---
B	756.7	178.0	445.3	104.8	311.4	73.2	1,690.0	1,690.0
C	176.1	---	142.5	---	33.5	---	*3.1287	---
E	59.7	4.3	48.0	3.5	11.7	0.8	1,183.7	385.0
F	171.2	17.1	22.1	3.1	16.8	2.1	2,548.5	1,385.2

*g/l

A bright red effluent was discharged from Substation B on 5-24-71. This appeared only once while collections were being made. The color was attributed to a red dye used and confirmed by a company official. The dye did not appear to be of significance with respect to mortality rate of test organisms. According to the official, this condition occurs not more than once every three or four months, and is not considered to merit special monitoring.

Combinations of Station I, Station III and Station VI effluents

Station I, Station III and Station VI effluents were combined in an attempt to determine possible synergistic and/or antagonistic effects. Equal mixtures of Station I and Station III effluents resulted in no mortality using N. crysoleucas as test organisms. Based on the results of these tests it may be said that the two effluents are antagonistic.

When using N. crysoleucas as test organisms and an equal mixture of Station I and Station VI effluents the TL_{50} value was 18.0% for 24, 48 and 96 hours. This TL_{50} value is higher than all but one 96 hour value recorded for Station I alone but not as high as some 96 hour values recorded for Station VI. Data indicate that equal mixtures of Station I and Station VI may tend toward stabilization of Station VI effluent while weakening the effects of Station I as reflected by use of N. crysoleucas as test organisms (Table 2 and Table 12). The variability in quality of Station VI effluent may, in future testing, lend different results.

Equal mixtures of Station I, Station III and Station VI effluents resulted in no mortality in successive tests. Based on this observation plus results of the above tests, it is indicative that Station III effluent may act as an antagonistic substance for both Station I and Station VI effluents. Results of combination values are shown in Table 16 and Figure 21.

The effluents used in the above combination of tests are considered to be the three most toxic of all effluents studied. When mixed equally there is a definite reaction. The tests indicate a general antagonistic effect. The respective plants are separated far enough from each other along the river that it is most likely that individual effects would probably have dissipated for the greater part before joining another. This is especially true of Station I and Station VI effluents.

Table 16. TL_{50} values in per cent of combination of Station I, Station III and Station VI effluents.

Date	24 hrs	48 hrs	96 hrs	Test Organism	Av.Wt.G.
Station I 50% and Station III 50%					
6-22-70	*	22.0	20.0	M. salmoides	1.4
6-22-70	*	25.0	25.0	M. salmoides	1.4
7-7-70	25.0	7.5	6.5	M. salmoides	1.6
7-7-70	21.5	7.5	6.0	M. salmoides	1.6
6-29-71	18.5	18.5	12.5	N. crysoleucas	2.1
6-29-71	18.5	18.5	14.0	N. crysoleucas	2.1
Station I 50% and Station VI 50%					
7-24-71	18.0	18.0	18.0	N. crysoleucas	2.1
Station I 33 1/3%, Station III 33 1/3% and Station VI 33 1/3%					
7-24-71	*	*	*	N. crysoleucas	2.2

*No mortality

Station VII: Sewage Treatment Plant in a Poor State of Repair (Imhoff-lagoon)

Effluent coming into the sewage treatment plant was checked in successive tests. The dissolved oxygen was less than 1 ppm and it was necessary to aerate the diluent water in higher concentrations in order for the test organisms, N. crysoleucas, to survive. The TL_{50} for 24 hours was 40.0%/37.5%, 37.0%/37.5% for 48 to 96 hours. Other characteristics of the effluent are as follows: pH 7.3, turbidity 33 JTU and dissolved solids 5,372 mg/l.

This sewage treatment plant is much smaller than the Station V sewage treatment plant. The toxicity of this inflowing fluid was not as

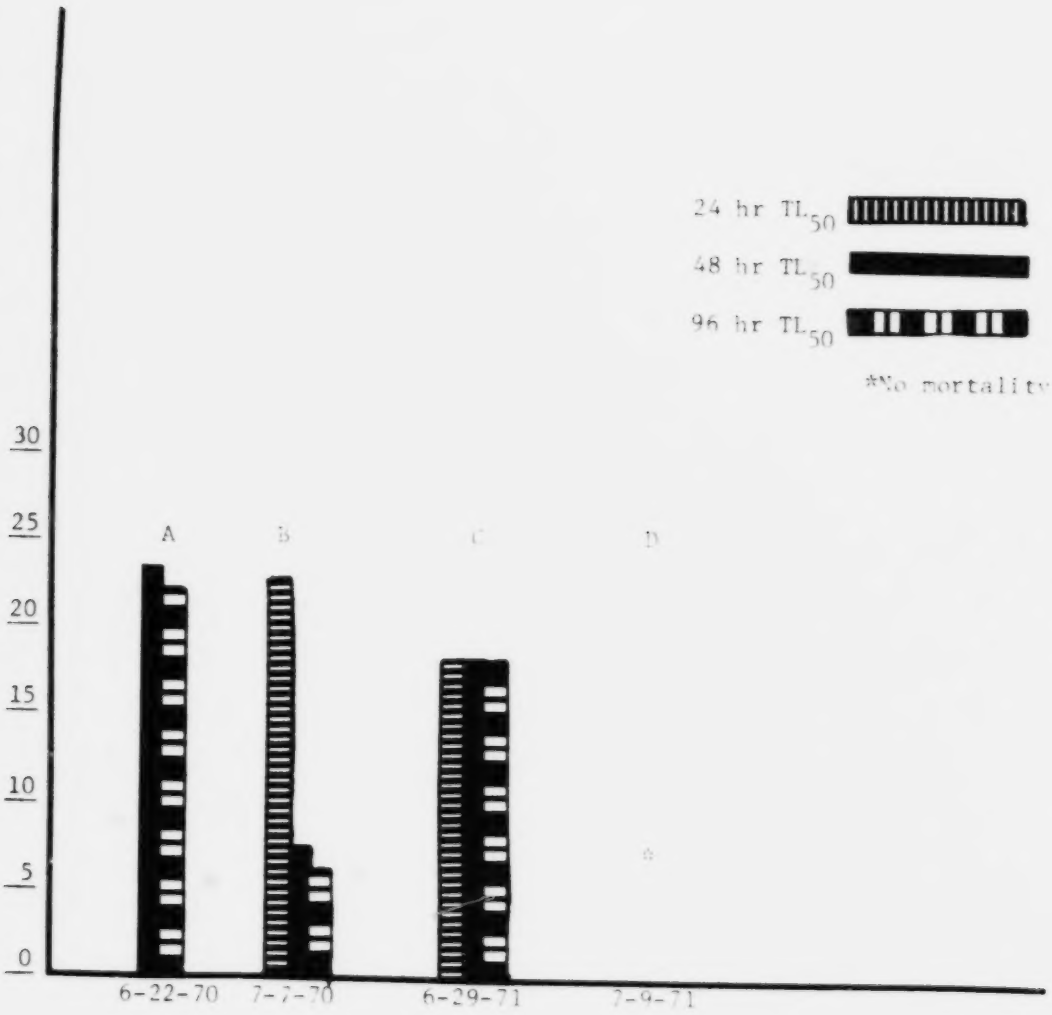

Figure 21. TL_{50} values for combinations of effluents.

A and B equal mixture of Station I and Station III using Micropterus salmoides as test organisms.

C equal mixture of Station I and Station III using Notemigonus crysoleucas as test organisms.

D equal mixture of Station I, Station II and Station III using Notemigonus crysoleucas as test organisms.

great as that of the Station V plant. This may be accounted for in part by the fact that the Station VII plant receives primarily domestic wastewater. The Station V sewage treatment plant receives a great amount of industrial wastewater in addition to the domestic.

Station VIII: Fuel Oil and Gasoline Bulk Loading Station

Effluents from the Station VIII contain primarily grease, lubricating oil and fuel oil, especially gasoline. There is rather extensive spillage of fuel resulting from carelessness in filling of tank trucks. The effluent is collected in a holding pit which may overflow into the Trinity River.

Other characteristics of the effluent are listed in Table 17.

Table 17. Characteristics of the Station VIII effluent.

Effluent	Value
Dissolved oxygen	4.6
pH	6.9
Turbidity	57.0 JTU
Conductivity	580 micromhos/cm
Total seston	34.65 mg/l
Abioseston	22.5 mg/l
Bioseston	12.5 mg/l
Dissolved solids	496.3 mg/l

The TL_{50} values for 24 hours was 18.75% and remained the same through 48 and 96 hours. The TL_{50} for a second test was 21.0% for 24, 48 and 96 hours.

Testing of this effluent was limited because the company was cognizant of the inadequacy of the system and started construction to remedy the situation.

Growth and Development

During the summers of 1970 and 1971 some 35 test runs (including duplicates) were carried out using fish eggs or fry as test organisms. Eggs or fry of the channel catfish (Ictalurus punctatus (Rafinesque)) were available for 29 of these tests while largemouth bass (Micropterus salmoides (Lacepede)) fry were used in the other six. One additional unsuccessful run using frog eggs was attempted early in 1971.

General Observations on 1970 Test Runs - The nine test runs carried out in 1970 are summarized in Table 18 (where starting date, source of effluent, range of concentration tested, total length of test and test organisms used in each are recorded). All involved the use of catfish eggs or newly-hatched young which became available from the Fort Worth National Fish Hatchery early in June.

The first duplicate test runs (I-AC(A) and I-AC(B)) were preliminary tests and did not lead to usable data but they did suggest several changes in apparatus and techniques which were incorporated in all subsequent tests on eggs or fry. These modifications are described in the "Materials and Methods" section of this report.

Of the remaining seven test runs for 1970 it will be noted that three used Station III effluent, two used Station I wastes and the last two tested a half-and-half mixture of these two commercial effluents. Three of the test runs (II-AC(A), II-AC(B) and III-AC(A)) were continued for a total of eight days while the others were discontinued at the end of four days. Data from these runs suggested that 96 hours is a satisfactory test period. However, it will be noted below under 1971 results that it was considered desirable to continue some of the 1971 test runs beyond the four day limit. The age of the catfish employed in the seven test runs of 1970 varied from three days pre-hatching (III-AC(A)) to 18 days post-hatching. Young at hatching averaged some 11 mm in length and these had reached an average length of 15 mm by 18 days of age. A total of 60 young fish were used in each series making a total of 420 for the seven runs.

Some general comments on the seven successful test runs involving catfish young carried out in June and early July of 1970 follow:

Series II-AC(A) and II-AC(B)-
Two simultaneous runs for total of eight days; Station III effluent; maximum concentration of 12 1/2%; young catfish six days of age post-hatching. All young fish were dead within 48 hours in strongest concentration and about half survived the full eight days in the 6 1/4% solution. All young fish survived the full eight days in the weaker concentrations and in the controls.

Series III-AC(A)-
Similar to above series except that the young used were about three days of age pre-hatching. Only three remained alive in the 12 1/2% solution after 48 hours and all were dead after 72 hours. All surviving young had hatched by the end of three days and the hatchlings survived well in all concentrations except the strongest (12 1/2%) for the full eight days.

Series I-TP(C) and I-TP(D)-
Two simultaneous runs for four days duration; Station I effluent; maximum concentration of 25%; young catfish of 18 days of age. All

Table 18. Summary of test runs involving eggs and fry (1970).

Run No.	Date Started	Effluent Station	Concentration Range Tested	Total Length of Test	Test Organisms
I-AC(A)	6-3-70	Station III	3.2 - 50%	42 hrs	Catfish eggs (4 days after spawning)
I-AC(B)	6-3-70	Station III	3.2 - 50%	4 days	Catfish eggs (4 days after spawning)
II-AC(A)	6-10-70	Station III	0.7 - 12.5%	8 days	Young catfish (6 days post-hatching)
II-AC(B)	6-10-70	Station III	0.7 - 12.5%	8 days	Young catfish (6 days post-hatching)
III-AC(A)	6-10-70	Station III	0.7 - 12.5%	8 days	Catfish eggs (about 3 days pre-hatching)
I-TP(C)	6-23-70	Station I	1.6 - 25%	4 days	Young catfish (18 days post-hatching)
I-TP(D)	6-23-70	Station I	1.6 - 25%	4 days	Young catfish (18 days post-hatching)
I-AC/TP(A)	6-23-70	1/2 Sta. I/1/2 Sta.III	1.6 - 25%	4 days	Young catfish (18 days post-hatching)
I-AC/TP(B)	6-23-70	1/2 Sta. I/1/2 Sta.III	1.6 - 25%	4 days	Young catfish (18 days post-hatching)

fish in these tests were dead within two and one-half hours in the strongest concentration (25%) and all were dead in the 12 1/2% tank within 24 hours. No fish survived for 48 hours in the 6 1/4% tank and only one fish survived in the 3 1/8% solution for the full four days. All survived in the 1 1/2% and control tanks for the full test period.

Series I-AC/TP(A) and I-AC/TP(B)-
Similar to preceding series except equal mixtures of Station III and Station I effluents were used. In these combined runs all fish survived for 24 hours in the 25% concentration, only 30% lived for 48 hours and none lasted for as long as three days. In the 12 1/2% test tank survival was 100% for one day, 95% for two days, 50% for three days and 40% for the full 96 hours. All fish survived in the three test tanks of lesser concentration and in the control tank.

General Observations on 1971 Test Runs - Table 19 gives in summary form starting dates, effluents tested, range of concentrations tested, length of test and test organisms used in all studies carried out on eggs or fry during the summer of 1971. A total of 27 test runs (including duplicates) were made and 20 of these employed catfish eggs or fry as test organisms. Young bass fry were used in six tests and one unsuccessful attempt was made to utilize frog eggs in the late gastrula stage.

Seven different pollutants or combinations thereof were tested in the 26 test runs involving fish eggs or fry. These were Station III (8), Station VI (9), Station I (3), Station VII (1), combination of 1/2 Station I and 1/2 Station III (2), combination of 1/2 Station I and 1/2 Station VI (1), combination of 1/3 Station I, 1/3 Station VI and 1/3 Station III (2).

The bass fry used in four of the test runs (Series II-A through IV-D) were obtained from the Fort Worth National Fish Hatchery on April 30, 1971 when they were about one week old. They were maintained in holding aquaria until used in the testing program. A fresh supply of fry was obtained from the hatchery for the tests of May 25, 1971 (Series V-A and VI-C).

Two lots of catfish eggs were obtained from the fish hatchery on June 1 and June 11, 1971. Hatching took place in the holding tanks in the laboratory and these furnished material for all tests through those of June 29. Three-week old fry obtained from the hatchery in early July provided test organisms for all tests conducted in July.

Twenty-three of the 26 tests lasted a minimum of 96 hours but several were continued for as long as ten days. The other three tests were discontinued prior to the four days and the results of these are not usable. In Series X-C the only survivors after 48 hours were the controls. Series XIV-A and XIV-B were terminated early also as all young catfish were dead at the end of 24 hours except for those in the weakest concentration and in the control tank.

Table 19. Summary of test runs involving eggs and fry (1971).

Run No.	Date Started	Effluent Station	Concentration Range Tested	Total Length of Test	Test Organisms
I-A	3-3-71	Station VI	0 - 100%	4 days	Frog eggs-gastrula stage
II-A	5-1-71	Station III	0 - 100%	4 days	Bass fry
III-A	5-12-71	Station III	0 - 100%	8 days	Bass fry
IV-C	5-18-71	Station VI(F)	0 - 20%	4 days	Bass fry
IV-D	5-18-71	Station VI(F)	0 - 20%	4 days	Bass fry
V-A	5-25-71	Station VI(F)	0 - 50%	4 days	Bass fry
VI-C	5-25-71	Station VI(B)	0 - 50%	4 days	Bass fry
VIII-A	6-2-71	Station III	0 - 25%	10 days	Catfish eggs (4 days pre-hatching)
VIII-B	6-2-71	Station III	0 - 25%	10 days	Catfish eggs (4 days pre-hatching)
IX-C	6-4-71	Station VI(F)	0 - 75%	4 days	Catfish eggs (3 days pre-hatching)
IX-D	6-4-71	Station VI(F)	0 - 75%	4 days	Catfish eggs (3 days pre-hatching)
X-C	6-10-71	Station VI(F)	0 - 100%	2 days	Catfish fry (6 days post-hatching)
XI-AA	6-12-71	Station VI(F)	0 - 10%	9 days	Catfish fry (8 days post-hatching)
XI-AB	6-12-71	Station VI(F)	0 - 10%	9 days	Catfish fry (8 days post-hatching)
XII-C	6-16-71	Station I	0 - 25%	10 days	Catfish fry (9 days post-hatching)
XII-D	6-16-71	Station I	0 - 25%	9 days	Catfish fry (8 days post-hatching)
XIII	6-21-71	Station I	0 - 25%	5 days	Catfish fry (9 days post-hatching)

Table 19. Continued

Run No.	Date Started	Effluent Station	Concentration Range Tested	Total Length of Test	Test Organisms
XIV-A	6-23-71	Station III	0 - 50%	1 day	Catfish fry (11 days post-hatching)
XIV-B	6-23-71	Station III	0 - 50%	1 day	Catfish fry (11 days post-hatching)
XV-A	6-25-71	Station III	0 - 20%	4 days	Catfish fry (13 days)
XV-B	6-25-71	Station III	0 - 20%	4 days	Catfish fry (13 days)
XVI-C	6-29-71	1/2 Sta. I/1/2 Sta.III	0 - 25%	6 days	Catfish fry (17 days)
XVI-D	6-29-71	1/2 Sta. I/1/2 Sta.III	0 - 25%	6 days	Catfish fry (17 days)
XVII-C	7-9-71	1/3 Sta. I/1/3 Sta.III/ 1/3 Sta. VI(F)	0 - 25%	4 days	Catfish fry (24 days)
XVII-D	7-9-71	1/3 Sta. I/1/3 Sta.III/ 1/3 Sta. VI(F)	0 - 25%	4 days	Catfish fry (24 days)
XIX-C	7-16-71	Station VII	0 - 50%	4 days	Catfish fry (31 days)
XX-A	7-24-71	1/2 Sta. I/1/2 Sta. VI(F)	0 - 25%	4 days	Catfish fry (39 days)

Observations and results for 1971 tests of fish eggs and fry are summarized below according to commercial effluent tested. The TL_{50} values reported here were determined in the same manner as described for mature fish in a preceding section of this report. The pH ranges shown are based on daily recording of acidity or alkalinity in the five test concentrations.

Station I: Railroad Equipment Cleaning Area

This effluent is regularly slightly basic and contains primarily detergents used in the various railroad cleaning operations.

Series XII-C and XII-D-
Duplicate tests with four day old catfish hatchlings were run with 25%, 12.5%, 6.25%, 3.13% and 1.56% concentrations of Station I effluent for a total of 10 days. The pH range and the 48- and 96-hour TL_{50} are given in Table 20 below. Surviving the full 10 days were seven fry in the 6.25%, 17 in the 3.13%, 19 in the 1.56% solution, and all 20 control organisms.

Series XIII-
A single run with seven day old fry was conducted simultaneously with the last five days of the preceding Series XII tests. Survival of these older fry was a bit better than those in Series XII; all fry survived in the solutions of 6.25% concentration or less. Two- and four-day TL_{50} values are shown in Table 20.

Table 20. TL_{50} values for eggs or fry using Station I effluent.

Series	pH Range	Test Organisms	TL_{50} Values		
			24 hrs	48 hrs	96 hrs
XII-C	7.8 - 8.5	Catfish fry (4-day)	--	18.5%	11.1%
XII-D	7.8 - 8.5	Catfish fry (4-day)	--	18.7	11.1
XIII	7.7 - 8.0	Catfish fry (9-day)	--	17.0	15.0

Station III: Chemical Plant Producing Cracking Catalysts for Processing Combustion Engine Fuels

This effluent exhibited wide variability in pH, being highly acidic or basic at different collection times. A white flocculent precipitate is frequently associated with this effluent. Eight test series (including duplicates) were carried out with this effluent; results are summarized below. TL_{50} values and pH ranges are shown in Table 21.

Series II-A-
A single run using bass fry with concentrations of 100%, 50%, 25%, 12.5% and 6.25% was continued for four days. Five fry were placed in each cup and two cups were placed in each tank. No fry survived in the two strong concentrations for 24 hours. There was 70% survival in the 25% tank for 48 hours and 40% survival for the full four days. All fry survived in the two weakest concentrations for the full test time. The pH ranged between 5.1 and 7.4.

Series III-A-
In this single eight-day test 20 bass fry (four cups of five fry each per tank) were subjected to concentrations of 50%, 25%, 12.5%, 6.25% and 3.12%. No fry survived in the 50% and 25% concentrations for 24 hours. Forty per cent survived 24 hours in the 12.5% tank but none survived for 48 hours. Ninety per cent of the test organisms survived for seven full days in the 6.25% tank at which time all died overnight. All fry survived in the weakest concentration for the full eight days. Variation in pH was 7.7 to 8.7.

Series VIII-A and VIII-B-
Duplicate tests with catfish eggs in concentrations of 25%, 12.5%, 6.25%, 3.13% and 1.56% were continued for a full ten days. Most of the eggs hatched out on the fourth day of the run. The number of eggs in each cup varied but a minimum of ten was included in each cup. The eggs were quite tolerant of the effluent as shown by the TL_{50} values in Table 21. It is possible that the egg membranes bestow increased protection to the developing embryos. Surviving the full 10-day period were 23% of the fry in the 6.25% concentration, 76% in the 3.13% and 71% in the 1.56% tank. Some 87% of the controls survived. The detection of a beating heart was the criterion used for determining survival. The pH in this series varied from 2.8 to 7.4.

Series XV-A and XV-B-
Duplicate tests with concentrations of 20%, 10%, 5%, 2.5% and 1.3% were continued for four days. Thirteen-day old catfish young were employed in these series. The pH varied in these tests from 2.3 to 7.2.

Table 21. TL_{50} values for eggs or fry using Station III effluent.

Series	pH Range	Test Organisms	TL_{50} Values		
			24 hrs	48 hrs	96 hrs
II-A	5.1 - 7.4	Bass fry	37%	37%	28%
III-A	7.7 - 8.7	Bass fry	14	12	11.5
VIII-A	2.8 - 7.4	Catfish eggs	--	14	14
VIII-B	2.9 - 7.5	Catfish eggs	24.5	19	17.9
XV-A	2.3 - 7.2	Catfish fry (13-day)	3.9	3.2	3.0
XV-B	2.3 - 7.2	Catfish fry (13-day)	4.6	4.2	3.6

Station VI: Metal Etching Plant Using Various Acids

Seven of the eight test runs summarized in Table 22 employed Station VI effluent from Substation F while effluent from Substation B was used in Series VI-C only. All of these effluents were alkaline varying from 7.7 to as high as 9.9. Observations on each of these test runs are summarized as follows:

Series IV-C and IV-D-
Station VI effluent in 20%, 10%, 5%, 2.5% and 1.3% were used in these tests. Bass fry were the test organisms. TL_{50} values at 24 and 48 hours were both 2.0% for Series IV-C and 2.6% for Series IV-D. As only 50% and 90% of the controls were surviving at 96 hours and as fry were also dying in holding tanks at this time the results from this test run are considered questionable.

Series V-A-
A new supply of bass fry from the hatchery was used in this single test with Station VI effluent at 50%, 25%, 12.5%, 6.3% and 3.1% concentrations. Although the fish were healthier, the TL_{50} values were about the same as in the Series IV runs. All fry in the highest four concentrations were dead overnight while five remained in the 3.1% solution through the entire 96-hour period. The pH ranged from 7.9 to 9.7.

Series VI-C-
This is the only test in which pollutant from Substation B was used. Young bass fry were test organisms. The effluent contained a bright red dye which is not a regular component of Station VI wastes. Concentrations in the five tanks were the same as in the Series V test. The pH varied from 7.7 to 9.6. The TL_{50} values remained constant (6.5%) at 24, 48 and 96 hours. Seven of the fry survived the full 96 hours in the weakest concentration. The red dye did make quite visible the copious secretion of mucus which coated the bodies and gills of the young fish.

Series IX-C and IX-D-
These duplicate tests used Station VI effluent in concentration of 75%, 37.5%, 18.8%, 9.4% and 4.7%. Catfish eggs in variable numbers were used for this four-day test. Many of the eggs hatched during the second or third day of the run. The pH varied 8.3 to 9.9 for this sample. Some 94% of the combined controls, 86% of young in the 4.7% tank, 38% from the 9.4% concentration, 3.6% from the 18.8% concentration, and 24% from the 37.5% tank remained alive at the end of the 96 hours.

Series XI-AA and XI-AB-
Station VI effluent was again used in these series. Catfish fry of five days of age were used in Series XI-AA while newly hatched catfish were used in the other series. These test runs were terminated at the end of nine days. The series of concentrations used here included 10%, 5%, 2.5%, 1.3% and .65%. There were no survivors of older fry in

the 10% tank after 48 hours, 20% survived in the 5% tank and 90 - 100% of the older fry lived through the full nine days. Survival of the younger fry was surprisingly higher as indicated by the TL_{50} values shown in Table 22.

Table 22. TL_{50} values for eggs or fry using Station VI effluent.

Series	pH Range	Test Organisms	TL_{50} Values		
			24 hrs	48 hrs	96 hrs
IV-C	7.7 - 9.1	Bass fry	2%	2%	--
IV-D	7.9 - 9.1	Bass fry	2.6%	2.6%	--
*VI-C	7.7 - 9.6	Bass fry	6.5%	6.5%	6.5%
IX-C	8.3 - 9.9	Catfish eggs	--	12.7%	9.8%
IX-D	8.3 - 9.4	Catfish eggs	52.5%	23.1%	--
XI-AA	7.9 - 8.9	Catfish fry, 5 day	4.5%	4.3%	4.3%
XI-AB	7.9 - 8.9	Catfish fry, newly hatched	--	5.6%	5.1%

*Substation B; all others from Substation F

Most of the studies to date have concerned themselves with effluent wastes from three commercial firms located along the Trinity River: a railroad equipment cleaning operation, a chemical plant producing cracking catalysts and a metal etching plant. In addition, a few tests have been conducted using combinations of these effluents and one test run was conducted using effluent from a suburban sewage treatment plant. The results of these test runs on young catfish are briefly summarized.

Series XVI-C and XVI-D-
Duplicate tests using a half-and-half mixture of Station I and Station III effluents were conducted. Maximum concentration was 25% and tests were continued for six days. Range of pH was marked - from 4.9 to 7.6. The TL_{50} estimates for 24, 48 and 96 hours were 16%/18.5%, 9.3%/16% and 5.5%/9.5% for the two series respectively.

Series XVII-C and XVII-D-
Duplicate tests using mixture of equal amounts of Station III, Station VI and Station I effluents. Maximum concentration was 25% and the test organisms were 24 day old catfish fry. The pH variation in these tanks was from 6.8 to 7.7. Sixty and 80% of the fry remained alive at the end of 24 hours; the TL_{50} estimates for 48 and 96 hours were 18.8%/20.5% and 10%/11.5% respectively.

Series XX-A-
Catfish fry (8 day of age) were tested in a half-and-half mixture of Station I and Station VI effluents. The run lasted five days. The pH range was from 7.6 to 8.9. The TL_{50} values were 5.8%, 4.3% and 3.5% for 24, 48 and 96 hours respectively.

Series XIX-C-
This single test used the supernatant of the inflow to the suburban sewage treatment plant (Station VII) diluted to 50%, 25%, 12.5%, 6.3% and 3.1% for a four-day test run. Catfish fry were 31 days of age. The TL_{50} figures for this run were 33%, 18.5% and 9% for 24, 48 and 96 hours respectively.

Catfish and bass fry which died in the various concentrations during each test run were examined under a low-power microscope for observable morphological damage prior to preservation. Some general observations are presented here. In most cases the dead fry exhibited excessive accumulations of mucus over the entire body and on the gills. The amount of mucus appeared to be more or less inversely proportional to the survival time. Mucus was particularly obvious on specimens exposed to stronger concentrations of Station III effluent where a white flocculent precipitate became trapped in the mucus over the body and within the gill cavity.

A corrosive effect on the skin and surface structures was quite noticeable on fish fry exposed to some of the more caustic or acidic test solutions. Barbels, opercular margin, caudal and other fins and gills showed various degrees of erosion. In some cases the skin on the belly wall was almost completely eroded through. These effects became progressively less noticeable as the survival time of the fry increased.

Examination of preserved specimens from all test runs is now being carried out in order to more specifically identify morphological damage.

Beginning with Series VII-A and VII-B surviving catfish fry from most of the test runs were transferred to floating plastic cups in a holding aquarium where they were maintained as long as possible. These survivors were fed daily with "starter food" and observed for damage. Survival counts were carried out periodically and dead fry were preserved for future examination.

Detailed results of these studies are not yet available but some generalizations can be made. "Post-test survival" ranged from only a day or two in some cases up to a maximum of almost ten weeks. Some of the fry (e.g., Station I, Series XII, 10% and Station III, Series VII, 6.2%) showed marked orientation problems, swimming upside down most of the time and feeding from floating food only. In other cups of survivors there appeared to be quite marked variation in growth over the length of the holding period.

Chemical Evaluation

Some chemical influences of industrial effluents discharged into the Trinity River were evaluated at six different stations. Five series of samples were collected at each station on different dates. Each station was subdivided into five substations. Each station is treated separately and specific values are included in the Appendix.

Station I: Railroad Equipment Cleaning Area

Three series of samples were collected in January 1970 and two in March. The sampling sequence was interrupted by construction along the channel. This station is on the Clear Fork of the Trinity River. All specific data are found in Appendices 1 - 5.

Temperature of the upstream station varied from 6°C - 14°C while that of the raw effluent at Substation B varied from 8°C - 18°C. Temperature of the three downstream Substations C, D and E varied from 6°C - 14°C. Air temperature during this period ranged between 4°C - 24°C (Appendices 1 - 5).

Dissolved oxygen ranged between 10.5 - 12.2 mg/1 for Substation A while for the raw effluent the range was between 4.0 - 9.4 mg/1. Downstream at Substations C, D and E DO ranged between 9.9 - 12.4 mg/1 (Appendices 1 - 5).

The pH value for Substation A ranged between 7.7 - 8.1 while for Substation B the range was between 10.3 - 11.5 and downstream values at Substations C, D and E ranged between 8.0 - 10.8 (Appendices 1 - 5).

Specific conductance ranged between 185 - 520 micromhos/cm at Substation A; Substation B was between 1,130 - 1,600 micromhos/cm and at C, D and E the range was between 230 - 1,000 micromhos/cm (Appendices 1 - 5).

Turbidity at Substation A ranged between 21 - 84 JTU, for B between 57 - 80 and for C, D and E between 23 - 76 (Appendices 1 - 5).

Phenolphthalein alkalinity at Substaion A was always 0.0 mg/1 as $CaCO_3$ while total alkalinity varied between 152 - 450 mg/1 as $CaCO_3$. Phenolphthalein alkalinity for Substation B ranged between 262 - 362 mg/1 as $CaCO_3$ and total alkalinity ranged between 428 - 638 mg/1 as $CaCO_3$. For Substations C, D and E phenolphthalein alkalinity ranged between 0.0 mg/1 as $CaCO_3$ and the total alkalinity ranged between 146 - 428 mg/1 as $CaCO_3$ (Appendices 1 - 5).

Biochemical oxygen demand values for Substation A ranged between 1.1 - 3.8 mg/1 while for Substation B it ranged between 15.2 - 23.8 mg/1. For Substations C, D and E the BOD values ranged between 0.0 - 22.0 mg/1 (Appendices 1 - 5).

Chemical oxygen demand value for Substation A was between 3.6 and 59.8 mg/l. Substation B ranged between 291.6 and 449.6 mg/l while Substations C, D and E ranged between 1.0 and 224.8 mg/l (Appendices 1 - 5).

The range of nitrate concentration at Substation A was between 0.0 mg/l NO_3 (0.0 mg/l NO_3-N) and 5.8 mg/l NO_3 (1.3 mg/l NO_3-N). The range for Substation B was between 0.2 mg/l NO_3 (0.04 mg/l NO_3-N) and 5.8 mg/l NO_3 (1.3 mg/l NO_3-N) while for Substations C, D and E the range was between 0.0 NO_3 (0.0 mg/l NO_3-N) and 6.6 mg/l NO_3 (1.5 mg/l NO_3-N) (Appendices 1 - 5).

Orthophosphate concentrations at Substation A ranged between 0.05 - 0.30 mg/l P, while hydrolyzable phosphate ranged between 0.00 mg/l and 0.03 mg/l P. Substation B had a range of orthophosphate from 0.58 mg/l P to 1.20 mg/l P and hydrolyzable phosphates ranged between 0.30 mg/l P and 1.30 mg/l P. Substations C, D and E ranged between 0.04 - 0.54 mg/l P for orthophosphate and ranged between 0.00 - 0.18 mg/l P.

Concentrations of dissolved calcium ranged between 56.0 - 86.5 mg/l for Substation A while for Substation B, the range was between 12.0 and 24.0 mg/l. The Substations C, D and E ranged from 20.4 - 70.3 mg/l. Dissolved magnesium concentrations ranged between 3.0 - 6.4 mg/l for Substation A, 0.2 - 3.6 mg/l for Substation B and from 3.6 - 7.6 mg/l for Substations C, D and E.

Concentrations of copper and zinc were all less than 0.25 mg/l for all substations while iron was less than 0.5 mg/l for all substations.

The per cent organic matter of the suspended matter for Substation A ranged between 14.9% - 33.0% while for Substation B, the range was from 46.9% - 59.5% and for Substations C, D and E the range for per cent organic was 11.8 - 36.6%.

The overall stream quality above and below the Station I outfall appears to be relatively the same. There does not appear to be any major change in the chemical characteristics of the stream below the outfall, but the effluent itself did effect the area directly around the discharge point. The fact that the downstream areas did not appear affected could be accounted for in part by the high discharge of the river at the time of sampling which diluted the effluent.

The temperature, DO, turbidity, nitrate concentration and trace metal concentrations of the effluent were within generally accepted levels (Rambow and Sylvester, 1967), but the pH, specific conductance, alkalinity, BOD, COD, phosphates and per cent organics were much greater than those values for the river. The values for dissolved calcium and magnesium were generally lower than those for the river (Appendices 1 - 5).

The values for pH, BOD, COD, alkalinity, phosphates and per cent organics indicate a future problem. During periods of low flow or no flow on the Clear Fork Trinity River, the Station I effluent could produce critical levels for these parameters and thus greatly affect the fish life present in the pools or shallow water of the river. Bioassays conducted on Station I effluent resulted in 96-hour TL_{50} values for minnows at concentrations of 4 - 9 per cent (Table 2, Figure 8). So, in itself, the effluent is very toxic, not withstanding the effects of the high BOD, COD, phosphates and greater per cent organics which would tend to deoxygenate the water if it were not reaerated. The low values for calcium and magnesium are probably due to precipitation as carbonate salts in the alkaline effluent. The high phenolphthalein alkalinity value reveals the presence of large amounts of carbonate ion. The Federal Water Pollution Control Administration (1968) recommends that the pH of a stream should not be raised above a value of 9.0 or lowered below 6.0 by highly dissociated materials. The values for the effluent generally were more than three units higher than the river. If the river had been at a lower discharge rate, the recommended values might have been exceeded. The FWPCA also recommends total phosphates of not more than 0.1 mg/l. This value may have been exceeded under a smaller discharge rate. Rambow and Sylvester (1967) suggested that the stream BOD not be increased by more than 2.0 mg/l due to a waste discharge. This value may well have been exceeded also during the low or no flow conditions. The high BOD and per cent organic values indicate that the full effect of the oxygen demand for the effluent was not shown by the BOD. The organic load may have a more pronounced effect at lower river discharge periods.

Station II: Storm Sewer Receiving Effluent from Small Industries and Some Untreated Sewage

Five series of samples were collected during February and March 1970. This station is located on the Clear Fork of the Trinity River. All specific data are listed in Appendices 6 - 10. During the collecting period the air temperature ranged between 13°C and 23°C. Water temperature for Substation A ranged between 14°C - 18°C. For B the range was between 17°C - 19°C and for C, D and E the range was between 14°C - 18°C.

Dissolved oxygen ranged between 7.2 - 9.8 mg/l at A, between 3.0 - 4.0 mg/l at B and between 6.8 - 10.0 mg/l at C, D and E.

Values for pH ranged between 7.0 - 8.2 at A, from 6.4 - 7.9 at B, and from 7.0 - 8.2 at C, D and E.

Measurements for specific conductance ranged between 500 - 530 micromhos/cm at A, from 650 - 1,480 micromhos/cm at B and from 500 - 560 micromhos/cm at C, D and E.

Turbidity ranged between 21 - 35 JTU at Substation A, between 17 - 42 JTU at B and between 20 - 34 JTU at C, D and E.

Phenolphthalein alkalinity was recorded as 0.0 mg/l as $CaCO_3$ for all samples. Recorded values for total alkalinity ranged between 188 - 220 mg/l as $CaCO_3$ at Substation A, from 222 - 294 mg/l as $CaCO_3$ at B and from 174 - 222 mg/l as $CaCO_3$ at C, D and E.

The ranges for BOD at Substation A were between 1.2 - 4.0 mg/l, at B between 13.6 - 32.0 mg/l and at C, D and E between 0.8 - 4.2 mg/l.

The COD ranged between 8.3 - 28.0 mg/l at Substation A, between 40.0 - 523.8 mg/l at B, and between 0.0 - 93.1 mg/l at C, D and E.

Nitrate concentrations observed ranged between 0.9 - 3.1 mg/l NO_3 (0.2 - 0.7 mg/l NO_3-N) at Substation A, between 3.1 - 5.8 mg/l NO_3 (0.7 - 1.3 mg/l NO_3-N) at B and between 0.4 - 3.5 mg/l NO_3 (0.1 - 0.3 mg/l NO_3-N) at C, D and E.

Orthophosphate observed at Substation A ranged between 0.02 - 10 mg/l, while B ranged between 0.24 - 1.32 mg/l P and C, D and E ranged between 0.03 - 0.12 mg/l P. Hydrolyzable phosphate had the following ranges: > 0.01 - 0.03 mg/l P at Substation A, 0.09 - 0.64 mg/l P at Substation B, >0.01 - 0.03 mg/l P at Substations C and D, and 0.02 - 0.04 mg/l P at Substation E.

Calcium has a concentration range of 75.2 - 91.2 mg/l at Substation A, 80.0 - 116.0 mg/l at B and 67.2 - 107.2 mg/l at C, D and E. Magnesium ranged from 4.4 - 6.0 mg/l at A, 5.2 - 9.6 mg/l at B and 4.0 - 6.8 mg/l at C, D and E.

Copper concentrations of all samples were less than 0.13 mg/l, while zinc were all less than 0.13 mg/l except one sample of the raw effluent had a zinc concentration of 0.35 mg/l.

Iron concentrations were all less than 0.50 mg/l.

Most parameters for this station were near those values for the stream. The only noticeably higher values were increases in BOD, COD, conductance, nitrates and phosphates (Appendices 6 - 10). The flow rate of the Station II effluent varied in accordance with rainfall.

The BOD and COD values were quite high for this effluent, but did not appear to greatly alter values downstream (Appendices 6 - 10). This was also true for nitrate and phosphate concentrations. It appeared that the effluent was assimilated into the stream without a change in stream values due to the small volume of effluent at the time samples were taken.

Station III: Chemical Plant Producing Cracking Catalysts for Processing Combustion Engine Fuels

Five series of samples were collected at Station III during February 1970. This station is on the Trinity River downstream from where the West Fork and Clear Fork of the Trinity join. All specific data are listed in Appendices 11 - 15. The air temperature of sampling days varied from -1°C to 10°C during this period (Figure 6, Appendices 11 - 15). The water temperature ranged between 2°C - 5°C at Substation A, between 13°C - 28°C at Substation B and 2°C - 18°C at Substations C, D and E.

Dissolved oxygen concentration ranged between 12.2 - 12.8 mg/1 at Substation A and 7.5 - 10.3 mg/1 at Substation B. The range was 8.0 - 12.8 mg/1 at C, D and E.

The pH value ranges at A, B, and C, D and E were 7.7 - 7.9, 5.3 - 11.9 and 6.2 - 9.6, respectively.

The range for specific conductance was between 400 - 520 micromhos/cm at A, from 1,150- greater than 8,000 micromhos/cm at B and from 635 - 6,000 micromhos/cm at C, D and E.

Turbidity ranged between 28 - 48 JTU at Substation A, from 36 - 95 JTU at B and from 25 - 91 JTU at C, D and E.

Phenolphthalein alkalinity was always 0.0 mg/1 as $CaCO_3$ at Substation A, while at Substation B the range was between 0.0 - 1,480 mg/1 as $CaCO_3$ and for C, D and E, it ranged between 0.0 - 276 mg/1 as $CaCO_3$. Total alkalinity at Substation A ranged between 156 - 196 mg/1 as $CaCO_3$, at B between 34.0 - 2,046 mg/1 as $CaCO_3$ and at C, D and E between 110 - 880 mg/1 as $CaCO_3$.

The BOD values at A ranged between 0.0 mg/1 to 3.7 mg/1, at B between 0.1 mg/1 to 1.7 mg/1 and at C, D and E it ranged between 0.0 to 3.8 mg/1.

The range of values for COD were between 0.0 - 22.0 mg/1 at A, between 12.0 - 148 mg/1 at B and between 0.0 - 124 at C, D and E.

The concentration of nitrate ranged between 0.0 mg/1 NO_3 (0.0 mg/1 NO_3-N) to 6.6 mg/1 NO_3 (1.5 mg/1 NO_3-N) at Substation A, from 7.1 mg/1 NO_3 (1.6 mg/1 NO_3-N) to greater than 177.2 mg/1 NO_3 (40.0 mg/1 NO_3-N) at B and between 2.2 mg/1 NO_3 (0.5 mg/1 NO_3-N) to 111.6 mg/1 NO_3 (25.2 mg/1 NO_3-N) at C, D and E.

Orthophosphate concentration at Substations A, B, and C, D and E ranged between 0.10 - 0.25 mg/1 P, 0.18 - 2.00 mg/1 P and between 0.02 - 0.88 mg/1 P, while hydrolyzable phosphates ranged between 0.00 mg/1 P to 0.10 mg/1 P at Substation A, between 0.00 mg/1 P to 0.12 mg/1 P at B and from 0.00 mg/1 P to 0.18 mg/1 at C, D and E.

Dissolved calcium ranged between 64.0 - 105.6 mg/l at Substation A, from less than 0.25 - 4.0 mg/l at B and between 2.4 mg/l to 8.8 mg/l at C, D and E.

Dissolved copper concentrations at all substations were always less than 0.25 mg/l.

Zinc concentrations were all less than 0.25 mg/l, except on two dates when a concentration of 1.0 mg/l was observed for B and on another date when 0.50 mg/l and 0.30 mg/l were recorded for B and C, respectively.

Values for iron were all recorded as less than 1.0 mg/l.

Organic carbon percentages for suspended matter ranged between 28.8 - 48.3 per cent at Substation A, from 17.9 - 24.1 per cent at B and between 18.6 - 31.7 per cent at C, D and E.

River discharges for the sampling days ranged between approximately 27 - 86 million gallons daily (Fort Worth Water Department).

The effluent from Station III appeared to have a great effect on the chemical quality of the stream below the outfall and for several hundred yards downstream.

The discharge from this station was generally a white to bluish color and quite turbid due to a floc. Downstream portions of the West Fork Trinity River were coated with this floc several inches deep in numerous places. What appeared to be deposits of the floc were found at another station a few miles downstream. The discharge rate is quite variable, ranging between a trickle to a very heavy flow.

Generally the effluent exhibits high temperature, extreme pH changes, high specific conductance, high turbidity, variable alkalinity, very high nitrate values and occasionally high phosphate concentrations (Appendices 11 - 15). The calcium and magnesium values were generally lower than those of the river (Appendices 11 - 15). During monitoring over a seven-hour period, pH value ranged between a low of 1.8 to a high of 7.5, while the temperature ranged between 22° and 30°C, the conductance value ranged from 2,050 to more than 8,000 micromhos/cm. Increased metabolism and degradation associated with the temperature elevation may reduce DO in the river. Rambow and Sylvester '967) recommend as a standard to maintain water quality that the discharge of effluents from industrial and domestic sources not be greater than 2°C above the natural temperature of the stream. The effluent is not within this recommendation.

The drastic changes in pH observed (Appendices 11 - 15), probably cause great stress on the organisms downstream from the outfall. The pH changes may cause reduction in their tolerance to temperature, certain metals and low DO. The FWPCA (1968) recommends that the pH of a stream

not be lowered below 6.0 or raised above 9.0 by discharge of waste. Station III effluent, during periods of low discharge rate of the Trinity River, would probably raise and/or lower the pH outside the standards set forth.

After studying reports compiled by the Fort Worth Water Department, it was concluded that the major cause of the high conductance of the Station III effluent was discharge of sulfate ions in large quantities. The conductivity downstream at times reached levels of 200% greater than upstream values (Appendices 11 - 15). This value exceeds Rambow and Sylvester (1967) by almost 75%, as they recommended that the conductivity not exceed 125% of the natural conductance of the river or stream, and preferably not more than 110% of natural values.

The turbidity revealed high concentrations of suspended matter. Although this matter has a relatively low organic content, the effects of the floc may be many. High concentrations of suspended material may, as mentioned, be in themselves harmful to fish by mechanically damaging their gills. The suspended matter also reduced penetration of light, thereby reducing the plant population downstream and limiting photosynthesis. The floc may affect the benthic fauna by coating the bottom to a depth of several inches covering the food sources and spawning areas. The FWPCA (1968) suggested that the turbidity not exceed 50 JTU in warm water streams due to waste discharges. This value was exceeded at times (Appendices 11 - 15).

The values for nitrate and phosphate in the stream increased greatly downstream from Station III outfall (Appendices 11 - 15). This probably stimulates growth of plankton and algae which cause an increased BOD due to their decomposition.

Rambow and Sylvester (1967) recommend no more than 0.4 mg/l increase in nitrates above natural values, as permissible, but state that ideally, no more than 0.1 mg/l increase should be permitted. For phosphates they recommend no more than a 0.15 mg/l increase over natural conditions in the stream, but also point out that a more desirable value would be no more than 0.03 mg/l increase in total phosphorus. The FWPCA (1968) states that the total phosphorus concentration should not be increased to a level above 0.1 mg/l P and that the natural nitrogen-phosphate ratio should be maintained. All these recommended values have been exceeded and at least for nitrates, significantly increased.

The overall effect of the Station III waste effluent it appears is to cyclically alter the natural conditions downstream from its outfall. The rapid change in pH, conductance and turbidity might be too great for most stream organisms to tolerate. It seems apparent that during periods of low river discharge, that this effluent could greatly reduce the fish population in the area downstream from the outfall, as well as seriously damage the benthic fauna.

Station V: Sewage Treatment Plant Receiving Industrial and Domestic Wastes

This sewage treatment plant is located on the northeast side of Fort Worth and discharges its effluent through two outlets into the Trinity River. Samples were collected in the vicinity of each outfall during June 1970. All specific data are found in Appendices 16 - 22.

The air temperature when sampling varied from 25°C - 30°C. Water temperature ranged between 27°C - 29°C at Substation A*, between 27°C - 28°C at B* and between 28°C - 30°C at C*, D* and E*. Water temperature ranged between 25°C - 29°C at B and between 25°C - 30°C at C, D and E.

Dissolved oxygen ranged between 4.8 - 10.2 mg/l at Substation A*, from 3.0 - 5.6 mg/l at B* and between 1.6 - 7.4 mg/l at C*, D* and E*. DO ranged between 5.4 - 7.2 mg/l at B and between 2.0 - 5.4 mg/l at C, D and E.

The pH values ranged between 7.4 - 7.8 at Substation A*, between 7.1 - 7.6 at B* and between 7.1 - 7.8 at C*, D* and E*. Values for pH at B ranged between 7.1 - 7.7 and between 7.3 - 7.8 at C, D and E.

Specific conductance ranged between 850 - 1,300 micromhos/cm at Substation A*, between 950 - 1,100 micromhos/cm at B* and between 660 - 1,250 micromhos/cm at C*, D* and E*. At Substation B and C, D and E the range was 975 - 1,100 micromhos/cm and 720 - 1,125 micromhos/cm, respectively.

Turbidity ranged between 16 - 28 JTU at Substation A*, between 20 - 43 JTU at B*, between 13 - 37 JTU at C*, D* and E*, between 13 - 23 JTU at B and between 12 - 32 JTU at C, D and E.

Phenolphthalein alkalinity was 0.0 mg/l as $CaCO_3$ for all samples analyzed. Total alkalinity ranged between 164 - 182 mg/l as $CaCO_3$ at Substation A*, between 220 - 306 mg/l as $CaCO_3$ at B* and between 174 - 216 mg/l as $CaCO_3$ at C*, D* and E*. The range for B and C, D and E were 202 - 298 mg/l as $CaCO_3$ and 186 - 238 mg/l as $CaCO_3$, respectively.

The BOD data for this station were particularly inconsistent and inconclusive.

The range of COD values was between 25.4 - 39.2 mg/l at Substation A*, 135.7 - 275.6 mg/l at B*, 38.2 - 76.3 mg/l at C*, D* and E*, 72.1 - 101.8 mg/l at B, and 42.4 - 89.0 at C, D and E.

Nitrate concentrations ranged between 2.8 - 13.3 mg/l NO_3 (0.6 - 3.0 mg/l NO_3-N) at Substation A*, from less than 0.1 mg/l NO_3 to 31.0 mg/l NO_3 (0.03 - 7.0 mg/l NO_3-N) at B* and from 0.9 - 11.5 mg/l NO_3

(0.2 - 2.6 mg/l NO_3-N) at C*, D* and E*. Values at B and C, D and F ranged between 21.3 - 48.7 mg/l NO_3 (4.8 - 11.0 mg/l NO_3-N) and 6.2 - 29.2 mg/l NO_3 (1.4 - 6.6 mg/l NO_3-N, respectively.

The effects of the sewage treatment plant effluent on the West Fork of the Trinity River were apparent by visual observation. The foam from detergents processed by the plant is carried down the river for several hundred yards. The foam alone creates serious ecological problems by limiting the amount of light that enters the water and by reducing reaeration of the stream water.

Only three parameters do not show a noticeable change from upstream values to downstream values - water temperature, pH and turbidity (Appendices 16 - 22).

Values for dissolved oxygen show a general depletion downstream from the effluent, at times approaching zero. This may be attributed to three major factors associated with the sewage treatment plant: high organic content in the effluent, high concentrations of both nitrogenous material and phosphates in the effluent and formation of foam which tends to lower or to maintain a low DO by preventing reaeration. The nitrates and phosphates promote growth of algae and aquatic plants. As the plants decompose available oxygen is utilized. The DO values reported reveal a serious threat to fish and other aquatic organisms. Ellis (1937) and FWPCA (1968) suggest that stream dissolved oxygen in warm water areas should be maintained above 5.0 mg/l for a good, varied warm water fish population. The FWPCA also states that DO values may fall below 5.0 mg/l for short periods but should not go below 4.0 mg/l or be maintained at 4.0 mg/l for any extended time. These values are not maintained in the river downstream from the sewage effluent.

Specific conductance varied in both the river and the effluent, but due to the high rate of discharge of the effluent, the conductance values for the river were affected by the effluent. The range was generally not great, but the change did show the lack of dilution water in relation to the volume of effluent discharged. At times the value exceeded the 125 per cent above natural conditions set as a standard by Rambow and Sylvester (1967).

The total alkalinity values for the effluent were generally much higher than those for the river. This was due probably to an increase in bicarbonates. Neel et al. (1963) found that decomposition and/or respiration both tended to increase bicarbonate concentration in raw sewage stabilization ponds. The increase in alkalinity in the river is noticeable but does not appear to be critical.

Biological [illegible] for the effluent were not conclusive. The results [illegible] Nearness to zero might be due to too great dilution of the effluent, [illegible] the phase for

bacterial growth so that full utilization of the organics present is not accomplished during the five-day period. Another possibility for inconsistent BOD results might be that the dilutions were so great as to reduce the organic material below a level to realize an oxygen demand. Data collected by the local water department show values for BOD for both plant effluents to average between 26 and 55 mg/l for those days sampled.

While the BOD results were inconsistent, the COD results showed that the organic matter present in the effluent was very high, and this effluent increased the COD value of the stream by almost three times. The discharge of organic material is probably the main reason for reduction of dissolved oxygen downstream from this plant. Rambow and Sylvester (1967) recommend that no more than 2.0 mg/l increase in stream BOD should be effected by a waste discharge. It is obvious that organic matter should not be added which might reduce the concentration of DO below required levels.

Nitrate concentrations for this station increased the stream nitrates by almost a factor of 10 (Appendices 16 - 22). Courchaine (1968) revealed that most nitrogenous wastes in wastewater exist as ammonia and organic nitrogen. When these were oxidized to nitrates, significant quantities of oxygen are consumed. Courchaine (1968) found that each mg/l of NH_3-N oxidized to nitrate was equivalent to 4.57 mg/l BOD. He reported that the single most important factor affecting stream DO was nitrification in the critical reaches downstream from a sewage treatment plant. Courchaine also stated that this nitrification accounted for 75 per cent of the total oxygen demand. Although ammonia concentration was not determined by this study, the Fort Worth Water Department (1970) showed ammonia concentrations of from 7 - 13 mg/l on those days when samples were collected. It can be seen that an additional oxygen demand of almost 60 mg/l would be exerted by the effluent in the river due to oxidation of NH_3-N to NO_3-N.

Orthophosphate and hydrolyzable phosphate levels were also high (Appendices 16 - 22). Values for both hydrolyzable and orthophosphates increased by almost a factor of 10 from the upstream to downstream from the outfall. The phosphorus level recommendations of the FWPCA (1968) and Rambow and Sylvester (1967) have not been maintained. The effect of the high phosphate concentration probably will be realized several miles downstream where the excessive growth of algae and other aquatic plants might create an unpleasant condition due to their mass decomposition. Metzler et al. (1958) reported that orthophosphate is seldom removed by sewage treatment plants.

Dissolved calcium and magnesium concentrations in the effluent appear to be somewhat lower than comparable values for the river. The possible cause for this might be due to the uptake in the human body or in the

microorganisms which inhabit the sewage treatment plant, or maybe the original source of the water was lower in calcium and magnesium than the river at this point.

The overall effect of this treatment plant appears to be a constant disturbance of the natural state of the river. With the continual discharge of sewage treatment plant effluent, a good, mixed fish fauna would not be able to inhabit the downstream region of this river effected by the discharge.

The effects might not be observed so easily during the winter months, but during the summer months when the river discharge is at its lowest, the sewage treatment plant's effluent may constitute 60 per cent or more of the total river discharge below the outfall. This can be pointed out more effectively by comparing the discharge rates of the river and effluent on those days sampled. During the sampling period, the river discharge ranged from about 13 - 20 mgd (preliminary unpublished data from U. S. Geol. Surv.) while the discharge rate of the effluent ranged from 25 - 33 mgd (Fort Worth Water Department data). As can be seen, the effluent at that time made up generally more than 50 per cent of the total discharge of the river downstream from the outfall. With lack of precipitation, it is not difficult to imagine the effluent comprising almost 100 per cent of the discharge of the river below the outfall.

Station IX: Small Tributary Receiving Effluents from Meat Packing and Rendering Plants

This station is a tributary of the Trinity River and receives wastes from the stockyards, packing houses and rendering plants. Five series of samples were collected during April 1970. All specific data are listed in Appendices 23 - 27.

The air temperature when sampling varied from 23°C - 27°C. The range of water temperature was between 19°C - 22°C at Substation A, upstream 19°C - 22°C at Substation B, the tributary and 19°C - 22°C for Substations C, D and E, downstream.

Dissolved oxygen measurements ranged between 8.6 - 9.2 mg/l at Substation A, between 8.2 - 9.0 mg/l at B and between 8.4 - 9.4 mg/l at C, D and E.

The pH values ranged between 7.4 - 7.9 at Substation A, 7.5 - 8.1 at B and between 7.3 - 7.0 at C, D and E.

Specific conductance varied from 390 - 450 micromhos/cm at Substation A, from 540 - 825 micromhos/cm at B and from 280 - 450 at C, D and E.

Turbidity measurements varied from 40 - 63 JTU at Substation A, 16 - 43 JTU at B and from 38 - 63 JTU at C, D and E.

The value for phenolphthalein alkalinity was 0.0 mg/l at $CaCO_3$ for all samples, while the total alkalinity ranged between 118 - 158 mg/l as $CaCO_3$ at Substation A, 126 - 228 mg/l as $CaCO_3$ at B and from 134 - 172 mg/l as $CaCO_3$ at C, D and E.

The BOD ranged from 1.4 - 1.8 mg/l at Substation A, 1.8 - 4.0 mg/l at B and from 0.0 - 1.9 mg/l at C, D and E.

A range from 10.0 - 22.4 mg/l at A, 16.6 - 19.9 mg/l at B and from 10.0 - 22.4 mg/l at C, D and E was observed for COD.

Nitrate ranges observed were less than 0.4 mg/l NO_3 (less than 0.1 mg/l NO_3-N) at Substation A. Values at B ranged between 2.2 - 8.0 mg/l NO_3 (0.5 - 1.8 mg/l) and at C, D and E less than 0.4 mg/l NO_3 (less than 0.1 mg/l NO_3-N) to 3.1 mg/l NO_3 (0.7 mg/l NO_3-N).

The orthophosphate range was between 0.05 - 0.09 mg/l P at Substation A, 0.09 - 0.42 mg/l P at B and 0.05 - 0.10 mg/l at C, D and E. Hydrolyzable phosphate ranged from less than 0.01 mg/l P to 0.01 mg/l P at Substation A, and C, D, E and from less than 0.01 mg/l at 0.04 mg/l P at B.

The concentration of calcium ranged between 42.0 - 54.0 mg/l at Substation A, between 60.0 - 82.0 mg/l at B and between 42.0 - 52.0 mg/l at C, D and E. Magnesium concentration varied between 4.8 - 6.4 mg/l at Substation A, between 3.6 - 4.8 mg/l at B and between 5.2 - 6.8 mg/l at C, D and E.

Values for copper, zinc and iron were less than 0.13 mg/l for all samples.

River discharges on sampling days ranged from approximately 389 - 1,620 million gallons daily (provisional advanced unpublished data collected by U.S.G.S. received from Fort Worth Water Department).

Station IX had generally higher values for nitrates, phosphates, specific conductance, pH, alkalinity, BOD and dissolved calcium than the West Fork Trinity but had lower values for turbidity and magnesium (Appendices 23 - 27). However, the entrance of Station IX had little apparent effect on the Trinity River.

The high values for nitrates and phosphates may be due to some industrial discharge, but are more likely due to domestic sources. The nitrates may be due to fertilizer runoff, (Task Group Report, 1967), while the phosphates may also be due to domestic runoff into storm sewers, (Task Group Report, 1967).

The values for pH, conductivity, alkalinity and dissolved calcium are probably due to closer contact with local geological formations. Station IX flows through a limestone area, and would have a tendency to take into solution more calcium and bicarbonate which would increase the alkalinity, pH and conductivity slightly.

The low values for turbidity for Station IX indicates that either the suspended matter draining into this station is low, or that it is low relative to the West Fork of the Trinity River, which was in a state of high discharge. The lower turbidity of Station IX may be due to drainage of an area which has more vegetation. The increase in BOD is slight, but might indicate organic contribution by urban runoff.

This station does not appear to strongly affect the character, either physically or chemically, of the West Fork of the Trinity River.

Station X: Tributary Receiving Effluents from Small Industries and a Food Packing Plant

Station X is a tributary of the Trinity River. It receives waste effluents from a food packing plant and other light industries. Five series of samples were collected during May 1970. All specific data are listed in Appendices 28 - 32.

The air temperature when sampling ranged from 24°C - 30°C. Water temperature measurements were 24°C for Substation A, upstream, but ranged between 23°C - 25°C for Substation B, C, D and E, the downstream substations.

Dissolved oxygen concentrations ranged between 5.0 - 8.8 mg/l at Substation A, between 6.8 - 11.0 mg/l at B and between 5.2 - 8.8 mg/l at C, D and E.

The value for pH ranged between 7.1 - 7.7 at Substation A, between 7.4 - 7.9 at B and from 7.0 - 7.8 at C, D and E.

Specific conductance had a range of 480 - 790 micromhos/cm at Substation A, 450 - 900 micromhos/cm at B and 495 - 780 micromhos/cm at C, D and E.

Ranges for turbidity were between 17 - 36 JTU at Substation A, 4 - 45 JTU at B and 18 - 37 JTU at C, D and E.

Values for phenolphthalein alkalinity were 0.0 mg/l at $CaCO_3$ at all substations. Total alkalinity ranged between 146 - 180 mg/l at $CaCO_3$ at Substation A, from 156 - 280 mg/l as $CaCO_3$ at B and between 144 - 182 mg/l as $CaCO_3$ at C, D and E.

The BOD values varied between 2.0 - 5.7 mg/l at Substation A, between 2.0 - 13.6 mg/l at B and between 1.7 - 6.4 mg/l at C, D and E.

The COD ranged between 20.0 - 25.9 mg/l at Substation A, between 20.0 - 59.4 mg/l at B and between 12.0 - 28.6 mg/l at C, D and E.

Nitrates were observed in the ranges of 2.8 - 5.3 mg/l NO_3 (0.6 - 1.2 mg/l NO_3-N) at Substation A, 0.9 - 4.9 mg/l NO_3 (0.2 - 1.1 mg/l NO_3-N) at B and of 2.2 - 6.3 mg/l NO_3 (0.5 - 1.4 mg/l NO_3-N) at C, D and E.

Orthophosphates ranged from 0.04 - 0.05 mg/l at Substation A, 0.25 - 1.32 mg/l P at B and between 0.03 - 0.29 mg/l P at C, D and E, while hydrolyzable phosphates ranged from less than 0.01 mg/l P to 0.05 mg/l P at Substation A, less than 0.01 mg/l P to 0.08 mg/l P at B and from less than 0.01 mg/l P to 0.07 mg/l P at C, D and E.

Calcium ranged between 58.0 - 62.0 mg/l at Substation A, between 54.0 - 102.0 at B and between 58.0 - 66.0 mg/l at C, D and E. Magnesium ranged between 5.8 - 7.4 mg/l at Substation A, between 5.2 - 12.8 mg/l at B and between 5.6 - 8.0 mg/l at C, D and E.

Values for copper, zinc and iron were all less than 0.13 mg/l.

Generally, the dissolved oxygen, pH, BOD, COD and phosphates at Station X were higher in the creek than in the river, while values for nitrate and turbidity were lower for the creek than the river (Appendices 28 - 32). The values for conductance, alkalinity, dissolved calcium and dissolved magnesium in the creek were quite variable (Appendices 28 - 32).

The higher DO values may be due to greater aeration in the more shallow creek or greater photosynthesis. The creek bottom was covered with plant growth, either algae or higher aquatic plants. The pH values for the creek were only slightly higher than for the river which may indicate the presence of a more alkaline drainage basin. The BOD and COD values were probably higher due to public littering and trash dumping. During previous preliminary investigations, it was noticed that some areas upstream were almost blocked by trash and litter. The BOD and COD could also have been increased by natural litter contributed by the many surrounding trees. Natural leaf litter could result in both a higher BOD and COD downstream. Another reason for increased BOD and COD might be due to runoff from local small industries.

Higher concentrations of phosphates at Station X than in the Trinity River may be indications of runoff from local car wash services, urban runoff or from natural deposits higher in phosphates.

Station X has a similar chemical character to that of the Trinity River. The junction of this creek with the Trinity River does not appear to cause any significant change in water quality downstream from this junction.

Trace Metal Investigation

A satellite investigation was conducted to determine concentrations of selected toxic metals in water and sediments of the Trinity River and Village Creek. Thirty-two water samples, 34 sediment samples and eight plating effluents were analyzed.

Copper was the only metal detected in excess of 0.1 ppb in all waters sampled, ranging between 2 and 52 ppb. Sediments contained up to 2,461 ppb copper, 1,604 ppb nickel, 126.0 ppb zinc, 221.5 ppb cadmium, 142.5 ppb lead and 1,200 ppb mercury. Effluents contained up to 300 ppb cadmium, 24.5 ppb mercury, 25 ppb copper, 320 ppm nickel, 13.0 ppm zinc and 147.5 ppm chromium. Sediments from the Industrial Area contained the highest concentrations, with outfalls and dumps being the most significant sources.

Benthos

Station I: Railroad Equipment Cleaning Area

Samples taken above Station I showed the greatest abundance and diversity of taxa with the most favorable conditions apparently existing in the center of the stream (Appendix 33). There was a total of 3,196 individuals and 14 taxa at this station as compared with 735 individuals and eight taxa at the station located at the mouth of the outfall (Appendix 34). Samples taken 70 yards below the discharge increased in diversity and abundance with 1,420 individuals and 11 taxa, while those about 150 yards downstream showed a reduction to 405 individuals and nine taxa (Appendices 35 - 36).

The reduction in diversity and numbers of individuals at the mouth of the outfall from those found upstream indicate an environmental stress does occur at this station. There are some variations in physical characteristics between these two stations. The depth is slightly greater at the mouth of the outfall and is partially protected from illumination by an overpass, but these factors should enhance rather than suppress the abundance of benthos. It was concluded, therefore, that the stress was due to the effluent at this site.

A considerable variation in abundance of benthos occurred at the two stations located downstream. The increase in number of organisms from samples 70 yards below the discharge was primarily due to the increase in abundance of oligochaetes. The river widens at this point and reduced current has resulted in deposition of fine sediments which favors an abundant oligochaete population. An overpass at this substation shades it from direct illumination during mid-day. The river narrows again at the site farthest downstream and the bottom

is very rocky resulting in a reduction of oligochaetes. The water is also more shallow at this point causing greater instability arising from seasonal fluctuation in water levels of the river (Appendices 33 - 36).

Station II: Typical Storm Sewer Receiving Effluent from Small Industrial Plants and Some Untreated Sewage

The dominant organisms at all of the substations were oligochaetes. Six hundred twenty-seven organisms representing eight taxa were taken at the station above the outfall (Appendix 37). A slight increase in numbers of oligochaetes was recorded at the mouth of the outfall (Appendix 38) and consequently a small increase in total number of organisms to 886. Six taxa were represented but this reduction was not considered significant since the groups which were missing occurred in such small numbers above the discharge. No significant changes in benthos occurred 70 yards downstream with 733 individuals and six taxa (Appendix 39). A significant increase was recorded 600 yards downstream in the oligochaete population which increased the total number of individuals to 1,215. This can be explained by the softer nature of the bottom sediments at this site. Eight taxa were found at this station (Appendix 40).

Core samples were taken above the outfall to determine the maximum depth of penetration by the benthos. Oligochaetes were the deepest burrowing organisms recovered, and they were found at depths up to 3 inches. These results correlated well with preliminary samples taken in April 1970. The effluent at Station II was judged to have very little effect on the invertebrate bottom fauna when compared to samples taken above the outfall (Appendices 37 - 40).

Station III: Chemical Plant Producing Cracking Catalysts for Processing of Combustion Engine Fuels

Four hundred twenty-five individuals representing ten taxa were found above the outfall (Appendix 41). Diptera larva and oligochaetes (Family Tubificidae) were predominant. Similar numbers were recorded from samples taken at the discharge with respect to total taxa (13) and number of individuals (343), but all of these were recorded from the center of the stream to the bank opposite the outfall (Appendix 42). There were no living organisms from the mouth of the outfall to mid-stream. Similar results were observed 30 yards downstream, the bottom being devoid of life under the plume of white floc (Appendix 43). Samples taken 150 yards down from the discharge showed some degree of recovery although the benthos was still quite sparse on the side of the river most influenced by the effluent (Appendix 44).

Whether the material was actually toxic to the organisms was not determined but the volume of suspended matter was judged to be sufficient to impair benthic life regardless of toxicity. Gammon (1970) found significant reductions in populations of macroinvertebrates resulting from increased loads of suspended inorganic solids. The volume of solids at this outfall was so great that any bottom dwelling organisms would probably be smothered by this material.

Benthic populations were established on the side of the river opposite the site of discharge since the river current carried the floc downstream. The benthos from midstream to the bank opposite the outfall approached that of samples taken above the discharge. Some degree of recovery was observed 150 yards downstream since much of the suspended solids had settled out by this time, but the very low population indicated there was still much stress on the benthic community (Appendices 43 - 44).

Station V: Sewage Treatment Plant Receiving Industrial and Domestic Wastes

There are two outfalls from the sewage treatment plant into the Trinity River. Samples were taken between the two outfalls just above and at the mouth of the lower one. Because of the increase in current velocity samples 7 - 10 could not be obtained at the mouth of the outfall. Samples below the lower outfall were not taken. Samples taken above the outfall showed a predominance of oligochaetes (Tubificidae) with nematodes being the second most abundant organisms (Appendix 45). There was a total of 1,339 individuals in the ten samples with six taxa represented.

A very drastic reduction in animals occurred at the mouth of the outfall. Although samples 7 - 10 could not be obtained at this station, there was an obvious difference of organisms in samples 1 - 5 (Appendix 46).

There was a considerable number of dead gastropods of the genus Physa. Only five tubificids, one dipteran (Tendipedidae) and one cyclopoid copepod were found in samples 1 - 5. Sample 6 was somewhat richer with 21 nematodes, three tubificids and two tendipedids.

The low dissolved oxygen and high organic content associated with streams polluted with sewage usually results in large numbers of tubificids (Pennak 1953). The absence of this group as well as others suited to this habitat is believed to result from the chlorination of the effluent prior to its release into the river. The concentrations of dead Physa may result in part from individuals in the sewage plant being killed by the chlorine and passing out with the effluent to settle into the river sediments. Since living Physa were found above the outfall, many of the dead snails may also result

from killing of individuals which move from above into the stream of chlorinated effluent. The current becomes quite strong near the center of the river causing the effluent to have less effect from midstream to the far bank. This is reflected in the increase in individuals in sample 6 taken near the center of the river (Appendices 45 - 46).

Station VI: Metal Etching Plant Using Various Acids

Twenty grab samples were taken at Station VI to see if organisms were able to live in the effluent. Five samples taken in the holding pool near the plant revealed no life. The effluent flows from the holding pool into an abandoned gravel pit. Five samples were taken along a transect across the entrance to the pit. Ten Odonata larvae and one coleopteran were recovered from the sample nearest the bank. Two transects consisting of five samples each were also taken across the two main pools in the gravel pit. No life was found at these stations.

Station IX: Small Tributary Receiving Effluents from Meat Packing and Rendering Plants

Five hundred thirty-two individuals representing 11 taxa were taken in samples above the junction of the tributary with the Trinity River (Appendix 47). Of these, 407 were dipteran larvae and 94 were oligochaetes (Tubificidae). At the mouth of the tributary there was a significant increase in the number of tubificids (446) and a slight decrease in dipterans (279). There was a total of 740 individuals and six taxa at this location (Appendix 48). The principal difference was in the increase in number of tubificids which probably resulted from increased organics. Thirty yards downstream the number of individuals increased to 1,160 and the taxa to eight, and at 150 yards the total count was 615 with eight taxa (Appendices 49 - 50). Dipteran larva and oligochaetes continued to be the dominant forms at these stations (Appendices 47 - 50).

Station X: Tributary Receiving Effluents from Small Industries and a Food Packing Plant

Nine taxa and 943 individuals with oligochaetes and dipterans the dominant organisms were collected at this station (Appendix 51). At the mouth of the tributary very little change was noted (Appendix 52). Oligochaetes and dipterans still predominated; the total number of taxa was six and the number of individuals was 1,064. The absence of three taxa at the mouth as compared with samples taken upstream was not considered significant since they occurred in such low abundance that sampling error could have accounted for their absence. A continued

abundance of dipterans and oligochaetes occurred at 70 and 150 yards downstream and there was a reduction in dipteran number at 150 yards (Appendices 53 - 54). There were 1,173 individuals with seven taxa 70 yards below and 1,076 individuals with eight taxa 150 yards below the junction of the tributary with the Trinity. The total number of individuals remained relatively constant. As oligochaete numbers increased, dipteran numbers decreased (Appendices 51 - 54).

SECTION VI

DISCUSSION

The Trinity River is a small stream of relatively low flow and in an area of somewhat limited precipitation especially during the summer months. Discharge of the river is due primarily to runoff and seepage from the drainage basin and controlled release from Benbrook Lake. The Clear Fork drainage area is a 518 square mile sector of North Central Texas while the West Fork drains 2,615 square miles of the same general area (Water Resources Data for Texas, 1969, 1970). Both have dams upstream which provide flood control, water supplies and recreation for the surrounding region. The West Fork has six major reservoirs upstream from Fort Worth which are primary sources of water supply for the urban area. Benbrook Lake is the main reservoir on the Clear Fork which is primarily a part of the Trinity River Flood Control System.

Average annual precipitation in the Fort Worth region approximates 31 inches (Climatological Data, Annual Summary, 1969, 1970). This area received 4.36 inches of rainfall above the annual average during 1969 and 4.77 inches in 1970. During the first seven months of 1971, only July received as much as the average amount of rainfall (Appendix 55). The low flow of the river resulted not only from limited precipitation but also from the fact that 83,510 acre-feet were retained in reservoirs of the West Fork for municipal and industrial use. In addition a total of 267 acre-feet were diverted from the Clear Fork for irrigation (Water Recources Data for Texas, 1969, 1970). However, added to this limited volume are discharges from industrial activities and sewage treatment plants. During months of low rainfall the greater percentage of volume in the river may be attributed to industrial effluents and discharge from sewage treatment plants. The above conditions contribute to the rather poor quality of the water in the Trinity River and afford a hazard for the biota present. Because of the limited volume of water from seepage and runoff, the possibility of alleviation of the undesirable effects of polluting effluents by dilution is quite remote.

Value of river, lake and reservoir waters is seriously impaired for recreational purposes even by relatively small loads of sediment (Gammon, 1970). Additives from domestic and industrial sources are detrimental to other uses of water. This appears to be particularly true of the Trinity River since much of its volume may result from such sources. A true evaluation of the effect of suspended substances, however, is difficult because of their diversity of origin. The effect on river biota of floc associated with effluents from a plant producing cracking catalysts had some semblance to that of various other types of sediment. Much of the study on effects of sediments on life in streams has been conducted in regions of mines and sediments resulting from mining activities (Cordone and Kelley, 1961). Results of such studies generally indicated adverse effects on stream organisms.

Many of the effluents involved in this study were quite turbid. Turbidity is usually an indicator of pollution. Turbidity reduces the euphotic zone which in turn limits photosynthesis and the release of much needed oxygen for aquatic life. This limits populations especially fish with respect to number and variety. Ellis (1937) did extensive turbidity studies and related adverse effects on fish. Associated with the most turbid of the effluents studied was a sizeable fish kill and repeated observations of fish floating lifelessly through the plume of the effluent being discharged. It has been found that various species of fish not only attempt to avoid turbid waters but alter their feeding habits and tend to migrate (Sumner and Smith, 1939; Bachman, 1958; Hofbauer, 1962). The heavy foaming associated with Stations ' and V effluents and floc of Station III are conditions that suggest possible migration of fish. However, fish surveys along the Trinity River were inconclusive as to quality, quantity and migratory activity because of channeling procedure, other construction and low water during the period of study.

The restricted size of the Trinity River coupled with the limited rainfall especially during the warmer months, renders this body of water quite vulnerable to industrial pollution. Almost any pollutant in sufficient concentration and given enough time can greatly impair or destroy a population. Some organisms such as fish may spend their entire lives in a given region and a severe pollutant may eliminate this species. A polluting agent from an outfall into a stream may block passage of organisms from one region to another thereby preventing their movement into breeding places. Copious amounts of inert substances in the effluent can result in various problems such as smothering spawn and fry, obliterating food supplies, concealing or destroying protective physical features and clogging the gills of fish resulting in possible decreased oxygen uptake. Of the industries investigated, the railroad cleaning area and cracking catalyst producing plant could readily contribute to the above conditions.

Domestic sewage and industrial pollution change water quality in streams (Matthews and Neuhold, 1967). It is well known that organic polluting substances greatly alter species structure and quality of both flora and fauna (Wilhm, 1967). Trautman (1933) relates the movement of fish upstream to a region above sewage outfalls especially when stress may be accentuated by low water and elevated temperature. Sewage and organic substances exert great effects on stream communities through uptake of oxygen beyond normal balance of respiration and photosynthesis in streams (Reid, 1961). Although fishes and other organisms may be tolerant to effluents containing sewage and similar wastes, indirect effects may be adverse to many species. Oxygen depletion reduces resistance of fish to pathogens, reduces agility thus limiting their ability to seek food and escape predators and may result in direct death. Scavenger type organisms may accumulate in these areas replacing predators. Katz and Gaufin (1952) found in their investigation that although several species of fish were

Station VI, the metal etching plant effluent from Substation A was the most toxic of all effluents checked. It was consistently very acid and extensive erosion of fin, gill and body tissues of fish was effected in a very short period of exposure. In 100% material, death of the test organisms often occurred within 30 seconds. Fluids from other substations did not have the severe effect on fish and strength or quality of the materials was more variable. Treatment of the waste fluids with lime did buffer the material and presumably rendered it less toxic. The company is cognizant of the toxicity of the effluent and has taken preliminary steps to alleviate such. Fortunately, the effluent goes into a holding pool and from there it is collected in large abandoned gravel pits but does not go directly into the river. Direct discharge of the effluent into the Trinity River would have a serious effect on all living organisms.

Bioassays using various species of mature fish (minnows), eggs and fry depicted a range of toxicity for respective effluents. Use of eggs and fry as test organisms proved very successful. In a number of the first tests involving fry, the fry of channel catfish appeared very rugged and survived as well as the young bass and golden shiners used in the same test. Eggs continued to develop and hatched in weak Station I effluent. In later tests conducted with eggs and fry of channel catfish using Station VI effluent, the channel catfish fry exhibited a greater susceptibility to the toxic materials than the golden shiner and fathead minnows being used simultaneously. Eggs appeared to be more tolerant to all solutions than young fry, probably due to protection provided by the embryonic membranes. It may be generally concluded from these results that eggs and fry can be used successfully as test organisms in bioassays to produce significant results. However, such tests are limited to a reasonably brief period of the year when spawn and fry are available.

The pattern of dispersal of the waste effluents in the river was determined by taking samples of the effluent and comparing with samples of river water from stations above the outfall, at the outfall and at various intervals downstream from the outfall. These samples were analyzed using as many as 18 chemical and/or physical parameters. From results of this phase of the investigation, it was concluded that the various effluents and the two tributaries appear to have a definite effect on water quality of the Trinity River. Station I and Station III cause a definite stressed condition downstream from the outfall that was not present above the outfall. The chemical data compiled on the river appear to agree well with daily reports of the Texas Water Development Board (December 1967) for the Clear Fork of the Trinity River at Fort Worth between 1949 and 1952 and with data collected at periodic times for the West Fork of the river at Fort Worth for 1952 through 1964. Ranges for a number of the parameters such as calcium, magnesium, alkalinity, nitrates, specific conductance and pH were within those determined by the Texas Water Development Board. The Texas Water Development Board (February 1970) expressed the opinion

that the Fort Worth area greatly affects the quality of the water in the Trinity River. Water from the Trinity River analyzed at Grand Prairie showed a marked increase in certain parameters over that of water taken upstream in the area of Fort Worth. There was a significant increase in the ranges of nitrates, phosphates, BOD and specific conductance. Phosphate and nitrate values increased by as much as 25 and 30 times respectively and BOD values increased by a factor of nine. Station II effluent could possibly be diluted sufficiently by the normal discharge of the river to prevent deleterious effects on the stream but Stations I, III and V could not be diluted sufficiently. Nicholson et al. (1970) noted that stream quality could be maintained if reservoir release upstream was controlled to allow the river to naturally assimilate the waste from a sewage treatment plant. To meet this requirement for the Trinity River, it would be necessary to tax to a greater extent the reserve in Benbrook Lake. It would also be necessary to accompany this by release of water from some of the six reservoirs on the West Fork of the Trinity River. Activity of this nature from the West Fork during the time most needed would probably deplete the water supply reserved for domestic and industrial uses beyond safe limits.

The stress placed on the Trinity River by introduction of domestic and industrial wastes as reflected by results of bioassay and chemical evaluation was supported for the greater part by the benthos study. It was the general pattern that at the stations discharging the more toxic effluents, organisms above the outfall were more numerous and the number and variety at the outfall were greatly reduced. In the area of the effluent plume, the number and variety of organisms remained reduced.

One would be in error to consider this study as all inclusive. Neither time nor facilities would permit an investigation of all or even a major percentage of the industries in Fort Worth. However, those selected for this project included a representative sampling and the results afford a good picture of the pollution situation along the Trinity River in the vicinity of Fort Worth and may well represent the problems of other cities downstream. In order for this metropolitan area to progress, it must keep abreast with the industrial development and its impact on the environment. This can be accomplished only through the promotion of further research of the type completed in this investigation.

SECTION VII

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SECTION VIII

REFERENCES

1. Bachmann, R. W., "The Ecology of Four North Idaho Trout Streams with Reference to the Influence of Forest Road Construction," Master's Thesis, Univ. Idaho, 97 pp (1958).

2. Bartsch, A. F. and W. S. Churchill, "Biotic Responses to Stream Pollution During Artificial Stream Reaeration. Limnological Aspects of Water Supply and Waste Disposal," Amer. Assn. Advancement Science, Washington D.C., 33-48 (1949).

3. Beadles, J. K., "The Effect of Domestic and Oil Refinery Effluents on Meristic and Morphometric Characteristics of Three Cyprinid Fishes," Thesis, Okla. State Univ., 94 pp (1966).

4. Black, J. D., "The Management and Conservation of Biological Resources," F. A. Davis Company, Philadelphia, 339 pp (1968).

5. Butterfield, C. T., "Experimental Studies of Natural Purification in Polluted Waters. III. A Note on the Relation Between Food Concentration in Liquid Media and Bacterial Growth," Public Health Reports, 44:2,865-2,872 (1929).

6. Butterfield, C. T. and W. C. Purdy, "Some Interrelationships of Plankton and Bacteria in Natural Purification of Polluted Water," Ind. & Eng. Chem., 23(2):213-218 (1931).

7. Charles, J. R., "Effects of Coal-Washer Wastes on Biological Productivity in Martin's Fork of the Upper Cumberland River," Kentucky Fish. Bull. No. 27-B, Ken. Dept. of Fish and Wildlife Resources, Frankfort, Ky. (1966).

8. Chu, H. F., "How to Know the Immature Insects," Wm. Brown Co., Iowa, 234 pp (1949).

9. "Climatological Data, Texas," U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, 76(1):1-31 (January 1971).

10. "Climatological Data, Texas," U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, 76(2):33-63 (February 1971).

11. "Climatological Data, Texas," U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, 76(3):65-95 (March 1971).

Preceding page blank

12. "Climatological Data, Texas," U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, 76(4):97-127 (April 1971).

13. "Climatological Data, Texas," U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, 76(5):129-158 (May 1971).

14. "Climatological Data, Texas," U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, 76(6):159-192 (June 1971).

15. "Climatological Data, Texas," U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, 76(7):193-251 (July 1971).

16. "Climatological Data, Texas," U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, 76(8):253-282 (August 1971).

17. "Climatological Data, Texas Annual Summary," U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, 74(13):405-430 (1969).

18. "Climatological Data, Texas Annual Summary," U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, 75(13):419-442 (1970).

19. Cordone, A. J. and D. W. Kelley, "The Influences of Inorganic Sediment on the Aquatic Life of Streams," Cal. Fish and Game, 47(2):189-228 (1961).

20. Courchaine, R. J., "Significance of Nitrification in Stream Analysis-Effects on the Oxygen Balance," Jour. Water Poll. Cont. Fed., 40(5) Pt. 1, 835 pp (1968).

21. Cross, F. B. and Braasch, M., "Qualitative Changes in the Fish-Fauna of the Upper Neosho River System, 1952-1967," Trans. Kansas Acad. Sci., 71. 350 (1969).

22. Doudoroff, P., "Some Recent Developments in the Study of Toxic Industrial Wastes," Proc. 4th Pacif. North West. Industr. Waste Conf., State Coll. of Washington, 21-25 (1952).

23. Eddy, S. and Hodson, A. C., "Taxonomic Keys to the Common Animals of the North Central States," Burgess Publ. Co., Minn. 162 pp (1961).

24. Edmondson, W. T., Editor, "Fresh Water Biology," John Wiley and Sons, Inc., 1,248 pp (1959).

5. Ellis, M. M., "Detection and Measurement of Stream Pollution," U. S. Department of Commerce, Bureau of Fisheries, Bull. No. 22 (1937).

6. Federal Water Pollution Control Administration, Water Quality Criteria, "Report of the National Technical Advisory Committee to the Secretary of the Interior," (April 1, 1968).

7. Federal Water Pollution Control Administration, "FWPCA Methods for Chemical Analysis of Water and Wastes," U. S. Department of the Interior, FWPCA, Div. of Water Quality Research, Analytical Quality Control Laboratory, 1014 Broadway, Cincinnati, Ohio, 280 pp (November 1969).

28. Forbes, S. A., "The Biological Survey of a River System--Its Objects, Methods and Results," Ill. State Department Registration Education, Div. Natural History Survey, 17(7):277-284 (1928).

29. Forbes, S. A. and Richardson, R. E., "Studies on the Biology of the Upper Illinois River," Ill. Natural History Survey Bull., 9(10): 481-574 (1913).

30. Forbes, S. A. and Richardson, R. E., "Some Recent Changes in Illinois River Biology," Ill. Natural History Survey Bull., 13(6):139-156 (1919).

31. Fort Worth Water Department, "Preliminary Data and Conversation" (1970).

32. FWCC, "Fort Worth Chamber of Commerce, Directory of Manufacturers," 42 pp (1969).

33. Gammon, J. R., "The Effect of Inorganic Sediment on Stream Biota," Water Pollution Control Research Series, 1805DDWC 12/70, 141 pp (1970).

34. Gaufin, A. R. and Tarzwell, C. M., "Aquatic Invertebrates as Indicators of Stream Pollution," U. S. Public Health Service Public Health Report, 67(1):57-64 (1952).

35. Graham, R. J. and Dorris, T. C., "Long-Term Toxicity Bioassay of Oil Refinery Effluents," Water Res. (Brit.), 2:643 (1968).

36. Hart, W. B., Doudoroff, P., and Greenbank, J., "The Evaluation of Industrial Wastes, Chemicals and Other Substances to Fresh-Water Fishes," A Contribution of the Waste Control Laboratory, Philadelphia, The Atlantic Refining Co. (1945).

37. Henderson, C., Pickering, Q. H., and Cohen, J. M., "The Toxicity of Synthetic Detergents and Soaps to Fish," Sewage Industr. Wastes, 31:295-306 (1959).

38. Henderson, C., Pickering, Q. H. and Tarzwell, C. M., "Relative Toxicity of Ten Chlorinated Hydrocarbon Insecticides to Four Species of Fish," Trans. Amer. Fish. Soc. 88:23-32 (1959).

39. Henderson, C., Pickering, Q. H. and Tarzwell, C. M., "The Toxicity of Organic Phosphorus and Chlorinated Hydrocarbon Insecticides to Fish," Trans. 1959 Seminar R. A. Taft Sanit. Eng. Center Tech. Rep. W 60-3 (1960).

40. Hofbauer, J., "Der Aufsteig der Fische in den Fishpassen des mehrfach gestauten Maines," Arch. Fisch Wiss. 13:92-125 (1963).

41. Hynes, H. B. N., "The Biology of Polluted Waters," Liverpool University Press, Liverpool, 202 pp (1960).

42. Jones, J. R. E., "Fish and River Pollution," Butterworths, London, 203 pp (1966).

43. Jones, J. R. E., "The Relative Toxicity of Salts of Lead, Zinc and Copper to the Stickleback (Gasterosteus aculeatus L.) and the Effect of Calcium on the Toxicity of Lead and Zinc Salts," J. Exp. Biol. 15:394-407 (1938).

44. Kalinske, A. A., "Practical and Technical Aspects of Reusing Effluent from Waste Treatment Plants," Proceedings, Seventh Industrial Water and Waste Conference, Texas Water Pollution Control Association, 161 pp (1938).

45. Katz, M. and Gaufin, A. R., "The Effects of Sewage Pollution on the Fish Population of a Midwestern Stream," Trans. Amer. Fish. Soc. 82:156-165 (1952).

46. Kussat, R. H., "A Comparison of Aquatic Communities in the Bow River Above and Below Sources of Domestic and Industrial Wastes from the City of Calgary," Can. Fish-Culturist, 40, 3(1969).

47. Lagler, K. L., "Freshwater Fishery Biology," Wm. C. Brown Company, Dubuque, Iowa, 421 pp (1956).

48. Mackenthun, K. M., "The Practice of Water Pollution Biology," U. S. Department of the Interior, Federal Water Pollution Control Administration, 281 pp (1969).

49. Matthews, J. E. and Neuhold, J. M., "Water Quality Effects on Fish Movement and Distribution," Utah Acad. Proceedings 44:275-297 (1967).

50. Metzler, D. F., Culp, R. L., Stoltenberg, H. A., Woodard, R. L., Walton, G., Chang, S. L., Clarke, N. A., Plames, C. M., and Middleton, F. M., "Emergency Use of Reclaimed Water for Potable Supply of Chanute, Kansas," JAWWA, 50:1,021 (August 1958).

51. Mount, D. I., "Test Animals for Water Quality," Amer. Fish Soc. Newsletter, 12(54):1-12 (1968).

52. Mount, D. I. and Brungs, W. C., "A Simplified Dosing Apparatus for Fish Toxicology Studies," Water Research, Pergamon Press, 1:21-29 (1967).

53. McDonald, D. B. and Schmickle, R. D., "Factors Affecting Winter Fish Kills in the Coralville Reservoir, Iowa," Proc. Iowa Acad. Sci., 72, 243 (1967).

54. Neel, J. K., Nicholson, H. P. and Hirsh, A., "Main Stem Reservoir Effects on Water Quality in the Central Missouri River," U. S. Department of Health, Education and Welfare, Public Health Service, Reg. VI, DWSPC, 112 pp (Mimeo 1963).

55. Nicholson, G. A., Pyatt, E. and Moreau, D. H., "A Methodology for Selecting Among Water Quality Alternatives," Water Resources Bull., 6, No. 1 (February 1970).

56. Patrick, R., "A Proposed Biological Measure of Stream Conditions, Based on a Survey of the Conestoga Basin, Lancaster County, Pennsylvania," Proc. Acad. Natural Sci. Philadelphia, 101:277-341 (1949).

57. Patrick, R., Cairns, J., Jr. and Scheier, A., "The Relative Sensitivity of Diatoms, Snails and Fish to Twenty Common Constituents of Industrial Wastes," Progr. Fish-Cult., 30, 137 (1968).

58. Pennak, R. W., "Freshwater Invertebrates of the United States," Ronald Press Co., N. Y., 769 pp (1953).

59. Penny, C. and Adams, C., "Fourth Report," Royal Commission on Pollution of Rivers in Scotland," London, 2:377-91 (1863).

60. Purdy, W. C., "Investigations of the Pollution and Sanitary Conditions of the Potomac Watershed, Potomac Plankton and Environmental Factors," U. S. Public Health Service Hyg. Lab., Bull. 104, 130-191 (1916).

61. Rambow, C. A. and Sylvester, R. O., "Methodology in Establishing Water Quality Standards," Jour. Water Poll. Control Fed. 39(7): 1,155 (July 1967).

62. Reid, G. K., "Ecology of Inland Waters and Estuaries," Reinhold Publishing Corporation, New York, 375 pp (1961).

63. Richardson, R. E., "Changes in the Bottom and Shore Fauna of the Middle Illinois River and Its Connecting Lakes Since 1913-1915 as a Result of the Increase, Southward, of Sewage Pollution," Ill. Natural History Survey Bull., 14:33-75 (1921).

64. "Standard Methods for the Examination of Water and Wastewater," Twelfth Edition, (1965).

65. Stephenson, J., "The Oligochaeta," Oxford University Press, London, 978 pp (1930).

66. Sumner, F. H. and Smith, O. R., "A Biological Study of the Effect of Mining Debris, Dams and Hydraulic Mining on Fish Life in the Yuba and American Rivers in California," U. S. District Engineers Office Sacramento, Calif. Stanford Univ. California, 51 pp (1939).

67. Task Group Report, "Sources of Nitrogen and Phosphorus in Water Supplies," AWWA Jour. 59:344-366 (1967).

68. Texas Water Development Board, Report 108, "Biochemical Oxygen Demand, Dissolved Oxygen, Selected Nutrients and Pesticide," Record of Texas Surface Waters, 1968 (February 1970).

69. Texas Water Development Board, Report 67, "Reconnaissance of the Chemical Quality of Surface Waters of the Trinity River Basin, Texas," Dec. 1967.

70. Trautman, M. B., "The General Effects of Pollution on Ohio Life," Trans. Am. Fish. Soc., 63:69-73 (1933).

71. Tsai, Chu-Fa, "Effects of Chlorinated Sewage Effluents on Fishes in Upper Patuxent River, Maryland," Chesapeake Sci., 9, 83 (1968).

72. "Water Resources Data for Texas," Part 1. Surface Water Records, U. S. Department of the Interior, Geological Survey, 593 pp (1969).

73. "Water Resources Data for Texas," Part 1. Surface Water Records, U. S. Department of the Interior, Geological Survey, 613 pp (1970).

74. Weston, R. S. and Turner, C. E., "Studies on the Digestion of a Sewage Filter Effluent by a Small Otherwise Unpolluted Stream," Mass. Inst. Technology, San Res. Lab. and Sew. Exp. Sta., 10:1-43 (1917).

75. Wheeler, A., "Fish-Life and Pollution in the Lower Thames: A Review and Preliminary Report," Biol. Conserv. (Brit.), 2, 1 (1969).

76. Wilhm, J. L., "Comparison of Some Diversity Indices Applied to Populations of Benthic Macroinvertebrates in a Stream Receiving Organic Wastes," Jour. WCPF 39:1,673-1,683 (1967).

77. Williams, L. G., Kopp, J. F. and Tarzwell, C. M., "Effects of Hydrographic Changes on Contaminants in the Ohio River," Jour. Amer. Water Works Assn., 58, 333 (1966).

SECTION IX

GLOSSARY

Abioseston - Nonliving substances suspended in the water.

Antagonism - Reduction of the effect of one substance because of the presence of another substance.

Benthos - Organisms which live in or on the bottom of the aquatic basin.

Bioseston - Living substances floating or swimming in water.

Biota - All life of a region.

BOD - Biochemical oxygen demand.

COD - Chemical oxygen demand.

Diluent - Diluting substance.

Euphotic - Region in water to a depth beyond which photosynthesis - effective light fails to penetrate.

Floc - Aggregation of fine suspended particles.

JTU - Jackson Turbidity Units--evaluation of turbidity.

MGD - Million gallons per day.

Micromho - Unit of electrical conductance--mho reciprocal of ohm.

ppm - Parts per million.

Seston - Mass of living or nonliving substances in water.

Synergism - Joint action of two or more substances is greater than the action of each of the individual substances.

Taxa - Taxonomic category of organisms.

Tubificid - Oligochaetes belonging to the taxonomic group Tubificidae.

Viscera - Internal organs.

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Appendix 1. Water chemistry analyses for Station I outfall, sampled January 12, 1970.

SUBSTATION	A_1	B_1	C_1	D_1	E_1
PARAMETER					
Temperature (°C)	6	8	7	6	6
Dissolved Oxygen mg/l	12.2	9.4	11.4	12.4	12.4
pH Value	7.9	11.1	10.8	8.7	8.1
Specific Conductivity (micromhos/cm)	400	1,300	1,000	410	410
Turbidity (JTU)	21	80	75	23	23
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	286	226	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	164	506	428	166	166
Biochemical Oxygen Demand (BOD) (mg/l)	2.8	20.8	21.6	3.4	4.0
Chemical Oxygen Demand (COD) (mg/l)	7.2	309.6	244.8	7.2	14.4
Nitrates NO_3					
mg/l NO_3-N	1.3	1.1	1.3	1.3	1.5
mg/l NO_3	5.8	4.9	5.8	5.8	6.6
Phosphate PO_4 as Orthophosphate (mg/l P)	0.05	0.66	0.54	0.05	0.05
Hydrolyzable Phosphate (mg/l P)	0.01	0.26	0.18	0.01	0.01
Calcium (mg/l)	*ND	ND	ND	ND	ND
Magnesium (mg/l)	ND	ND	ND	ND	ND
Copper (mg/l)	ND	ND	ND	ND	ND
Zinc (mg/l)	ND	ND	ND	ND	ND
Iron (mg/l)	ND	ND	ND	ND	ND
PER CENT Organic	ND	ND	ND	ND	ND

*ND - Not Determined.

Appendix 2. Water chemistry analyses for Station I outfall, sampled January 15, 1970.

SUBSTATION	A_2	B_2	C_2	D_2	E_2
PARAMETER					
Temperature (°C)	7	8	7	7	7
Dissolved Oxygen mg/l	12.0	9.4	11.2	12.0	11.8
pH Value	7.9	11.1	9.2	8.0	8.0
Specific Conductivity (micromhos/cm)	510	1,250	500	515	510
Turbidity (JTU)	24	57	39	23	24
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	344	70	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	266	546	298	256	246
Biochemical Oxygen Demand (BOD) (mg/l)	1.1	23.8	22.0	1.6	1.6
Chemical Oxygen Demand (COD) (mg/l)	3.6	291.6	79.2	0.0	0.0
Nitrates NO_3					
mg/l NO_3-N	0.8	0.8	0.5	1.0	0.8
mg/l NO_3	3.5	3.5	2.2	4.4	3.5
Phosphate PO_4 as Orthophosphate (mg/l P)	0.12	0.58	0.24	0.10	0.10
Hydrolyzable Phosphate (mg/l P)	0.01	0.34	0.02	0.01	0.01
Calcium (mg/l)	76.8	16.0	20.4	72.0	76.8
Magnesium (mg/l)	3.0	3.6	3.6	7.6	6.0
Copper (mg/l)	<0.25	<0.25	<0.25	<0.25	<0.25
Zinc (mg/l)	<0.13	<0.13	<0.13	<0.13	<0.13
Iron (mg/l)	ND	ND	ND	ND	ND
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 3. Water chemistry analyses for Station I outfall, sampled January 27, 1970.

SUBSTATION	A_3	B_3	C_3	D_3	E_3
PARAMETER					
Temperature (°C)	9	11	9	9	8
Dissolved Oxygen mg/l	11.0	8.2	11.2	10.8	11.4
pH Value	7.9	11.5	8.5	8.0	8.1
Specific Conductivity (micromhos/cm)	520	1,600	565	560	535
Turbidity (JTU)	84	57	66	72	71
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	362	10.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	450	638	280	300	280
Biochemical Oxygen Demand (BOD) (mg/l)	2.8	21.8	7.2	3.2	3.2
Chemical Oxygen Demand (COD) (mg/l)	59.8	373.1	31.6	7.0	8.5
Nitrates NO_3					
mg/l NO_3-N	1.3	1.3	1.5	1.3	1.0
mg/l NO_3	5.8	5.8	6.6	5.8	4.4
Phosphate PO_4 as Orthophosphate (mg/l P)	0.30	0.69	0.23	0.20	0.21
Hydrolyzable Phosphate (mg/l P)	<0.01	>0.50	0.06	0.03	0.02
Calcium (mg/l)	86.5	12.0	70.3	67.1	51.2
Magnesium (mg/l)	6.4	0.2	6.0	6.0	4.8
Copper (mg/l)	<0.25	<0.25	<0.25	<0.25	<0.25
Zinc (mg/l)	<0.13	<0.13	<0.13	<0.13	<0.13
Iron (mg/l)	ND	ND	ND	ND	ND
PER CENT Organic	14.9	59.5	16.2	29.2	11.8

Appendix 4. Water chemistry analyses for Station I outfall, sampled March 3, 1970.

SUBSTATION	A_4	B_4	C_4	D_4	E_4
PARAMETER					
Temperature (°C)	14	18	14	14	14
Dissolved Oxygen mg/l	10.5	4.4	9.9	10.6	10.5
pH Value	8.1	10.3	8.1	8.3	8.1
Specific Conductivity (micromhos/cm)	330	1,130	340	325	230
Turbidity (JTU)	73	69	76	74	76
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	266	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	258	470	268	256	236
Biochemical Oxygen Demand (BOD) (mg/l)	3.8	15.2	5.4	3.4	3.2
Chemical Oxygen Demand (COD) (mg/l)	46.2	449.6	37.8	25.2	25.2
Nitrates NO_3					
mg/l NO_3-N	0.7	1.0	0.7	0.7	1.0
mg/l NO_3	3.1	4.4	3.1	3.1	4.4
Phosphate PO_4 as Orthophosphate (mg/l P)	0.27	1.20	0.18	0.11	0.22
Hydrolyzable Phosphate (mg/l P)	<0.01	1.30	< 0.01	0.12	0.01
Calcium (mg/l)	56.0	20.8	56.0	56.0	56.0
Magnesium (mg/l)	4.0	0.4	4.4	4.0	4.4
Copper (mg/l)	<0.25	<0.25	<0.25	<0.25	<0.25
Zinc (mg/l)	<0.25	<0.25	<0.25	<0.25	<0.25
Iron (mg/l)	<0.25	<0.25	<0.25	<0.25	<0.25
PER CENT Organic	28.2	46.9	25.4	ND	13.2

Appendix 5. Water chemistry analyses for Station I outfall, sampled March 5, 1970.

SUBSTATION	A_5	B_5	C_5	D_5	E_5
PARAMETER					
Temperature (°C)	11	16	12	12	12
Dissolved Oxygen mg/l	11.3	4.0	11.2	11.1	11.1
pH Value	7.7	10.3	8.6	7.8	7.8
Specific Conductivity (micromhos/cm)	185	1,130	400	350	350
Turbidity (JTU)	30	63	38	27	29
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	262	30	0.0	0.0
total alkalinity (mg/l)	152	428	186	154	146
Biochemical Oxygen Demand (BOD) (mg/l)	1.2	17.0	8.5		1.4
Chemical Oxygen Demand (COD) (mg/l)	21.0	348.6	46.2	8.4	16.8
Nitrates NO_3					
mg/l NO_3-N	<0.1	0.04	0.03	<0.1	<0.1
mg/l NO_3	<0.1	0.18	0.13	<0.1	<0.1
Phosphate PO_4 as Orthophosphate (mg/l P)	0.12	1.2	0.18	0.05	0.04
Hydrolyzable Phosphate (mg/l P)	0.03	0.92	0.08	0.01	0.02
Calcium (mg/l)	60.8	24.0	60.8	60.8	60.8
Magnesium (mg/l)	5.2	2.4	6.0	6.0	5.2
Copper (mg/l)	<0.25	<0.25	<0.25	<0.25	<0.25
Zinc (mg/l)	<0.25	<0.25	<0.25	<0.25	<0.25
Iron (mg/l)	<0.5	<0.5	<0.5	<0.5	<0.5
PER CENT Organic	33.0	49.2	36.6	29.2	34.4

Appendix 6. Water chemistry analyses for Station II outfall, sampled March 25, 1970.

SUBSTATION	A_1	B_1	C_1	D_1	E_1
PARAMETER					
Temperature (°C)	16	18	17	16	16
Dissolved Oxygen mg/l	9.0	3.6	9.2	8.4	8.6
pH Value	7.0	6.4	7.2	7.0	7.0
Specific Conductivity (micromhos/cm)	500	800	500	500	500
Turbidity (JTU)	35	42	31	31	30
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	200	294	200	196	210
Biochemical Oxygen Demand (BOD) (mg/l)	3.0	1/1- 4.6 1/2-13.6	3.8	3.4	2.1
Chemical Oxygen Demand (COD) (mg/l)	19.4	523.8	15.5	93.1	15.5
Nitrates NO_3					
mg/l NO_3-N	0.7	1.3	1.0	0.7	0.7
mg/l NO_3	3.1	5.8	4.4	3.1	3.1
Phosphate PO_4 as Orthophosphate (mg/l P)	0.10	0.24	0.07	0.07	0.10
Hydrolyzable Phosphate (mg/l P)	0.02	0.36	0.01	0.03	0.02
Calcium (mg/l)	83.2	102.4	67.2	68.8	91.2
Magnesium (mg/l)	4.4	8.0	6.4	6.0	4.0
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	0.35	<0.125	<0.125	<0.125
Iron (mg/l)	<0.5	<0.5	<0.5	<0.5	<0.5
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 7. Water chemistry analyses for Station II outfall, sampled March 27, 1970.

SUBSTATION	A_2	B_2	C_2	D_2	E_2
PARAMETER					
Temperature (°C)	14	17	14	14	14
Dissolved Oxygen mg/l	9.8	3.0	10.0	9.4	9.0
pH Value	8.2	7.5	8.1	8.2	8.1
Specific Conductivity (micromhos/cm)	530	740	560	550	540
Turbidity (JTU)	27	23	28	28	27
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	220	250	220	214	222
Biochemical Oxygen Demand (BOD) (mg/l)	1.2	1/1- 5.2 1/2-12.4	2.8	0.8	1.2
Chemical Oxygen Demand (COD) (mg/l)	8.3	166.4	8.3	8.3	4.2
Nitrates NO_3					
mg/l NO_3-N	0.5	0.7	0.7	0.5	0.5
mg/l NO_3	2.2	3.1	3.1	2.2	2.2
Phosphate PO_4 as Orthophosphate (mg/l P)	0.10	0.38	0.12	0.09	0.10
Hydrolyzable Phosphate (mg/l P)	>0.01	0.30	0.01	>0.01	0.02
Calcium (mg/l)	91.2	91.2	107.2	91.2	86.4
Magnesium (mg/l)	4.8	7.2	6.0	5.6	6.8
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.5	<0.5	<0.5	<0.5	<0.5
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 8. Water chemistry analyses for Station II outfall, sampled April 1, 1970.

SUBSTATION	A_3	B_3	C_3	D_3	E_3
PARAMETER					
Temperature (°C)	16	18	16	16	16
Dissolved Oxygen mg/l	7.6	4.0	9.2	8.0	10.0
pH Value	8.1	7.9	8.1	8.1	8.0
Specific Conductivity (micromhos/cm)	520	770	520	520	520
Turbidity (JTU)	35	21	34	32	29
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	188	254	204	198	198
Biochemical Oxygen Demand (BOD) (mg/l)	1.2	1/1- 9.2 1/2-22.4	1.4	1.8	1.8
Chemical Oxygen Demand (COD) (mg/l)	20.6	182	8.2	4.1	>1.0
Nitrates NO_3					
mg/l NO_3-N	0.7	1.2	0.6	0.6	0.5
mg/l NO_3	3.1	5.3	2.7	2.7	2.2
Phosphate PO_4 as Orthophosphate (mg/l P)	0.05	1.20	0.05	0.05	0.05
Hydrolyzable Phosphate (mg/l P)	0.03	0.64	0.02	0.03	0.03
Calcium (mg/l)	75.2	80.0	83.2	75.2	78.4
Magnesium (mg/l)	6.0	6.8	6.0	6.0	6.0
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.123	<0.123	<0.123	<0.123	<0.123
Iron (mg/l)	<0.5	<0.5	<0.5	<0.5	<0.5
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 9. Water chemistry analyses for Station II outfall, sampled April 7, 1970.

SUBSTATION	A_4	B_4	C_4	D_4	E_4
PARAMETER					
Temperature (°C)	16	18	17	17	17
Dissolved Oxygen mg/l	7.2	3.0	7.2	7.2	8.4
pH Value	7.6	7.6	7.9	7.8	7.9
Specific Conductivity (micromhos/cm)	500	1,480	510	520	500
Turbidity (JTU)	21	17	27	27	31
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	184	222	178	200	176
Biochemical Oxygen Demand (BOD) (mg/l)	4.0	1/1- 4.7 1/2-13.8 1/4-22.4	3.6	3.8	4.2
Chemical Oxygen Demand (COD) (mg/l)	28.0	40.0	16.0	24.4	12.2
Nitrates NO_3					
mg/l NO_3-N	0.4	1.0	0.5	0.6	0.5
mg/l NO_3	1.8	4.4	2.2	2.7	2.4
Phosphate PO_4 as Orthophosphate (mg/l P)	0.03	0.49	0.03	0.05	0.12
Hydrolyzable Phosphate (mg/l P)	0.02	0.09	0.02	0.05	0.04
Calcium (mg/l)	84	116	72	76	72
Magnesium (mg/l)	5.6	9.6	4.8	5.6	5.6
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.5	<0.5	<0.5	<0.5	<0.5
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 10. Water chemistry analyses for Station II outfall, sampled April 9, 1970.

SUBSTATION	A_5	B_5	C_5	D_5	E_5
PARAMETER					
Temperature (°C)	18	19	18	18	18
Dissolved Oxygen mg/l	7.2	3.2	6.8	6.8	7.0
pH Value	8.0	7.7	8.0	8.0	8.0
Specific Conductivity (micromhos/cm)	500	650	520	520	500
Turbidity (JTU)	20	21	20	20	25
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	188	238	196	174	182
Biochemical Oxygen Demand (BOD) (mg/l)	3.4	1/1- 5.2 1/2-12.4 1/4-32.0	3.0	3.2	3.4
Chemical Oxygen Demand (COD) (mg/l)	16.0	72.0	20.0	20.0	20.0
Nitrates NO_3					
mg/l NO_3-N	0.2	0.7	0.1	0.8	0.1
mg/l NO_3	0.9	3.1	0.4	3.5	0.4
Phosphate PO_4 as Orthophosphate (mg/l P)	0.02	1.32	0.05	0.05	0.08
Hydrolyzable Phosphate (mg/l P)	0.03	>0.62	0.03	0.02	0.04
Calcium (mg/l)	78.0	86.0	80.0	76.0	76.0
Magnesium (mg/l)	5.6	5.2	5.2	5.2	5.6
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.5	<0.5	<0.5	<0.5	<0.5
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 11. Water chemistry analyses for Station III outfall, sampled February 5, 1970.

SUBSTATION	A_1	B_1	C_1	D_1	E_1
PARAMETER					
Temperature (°C)	2	28	16	2	2
Dissolved Oxygen mg/l	12.8	8.0	8.8	12.0	12.8
pH Value	7.8	11.9	9.6	8.0	8.2
Specific Conductivity (micromhos/cm)	500	>8,000	2,800	650	635
Turbidity (JTU)					
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	1,480	118	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	188	2,046	256	194	196
Biochemical Oxygen Demand (BOD) (mg/l)					
Chemical Oxygen Demand (COD) (mg/l)					
Nitrates NO_3					
mg/l NO_3-N	<0.1	>1.0	>1.0	0.5	0.5
mg/l NO_3	<0.1	>4.4	>4.4	2.2	2.2
Phosphate PO_4 as Orthophosphate (mg/l P)	0.15	0.30	0.02	0.13	0.13
Hydrolyzable Phosphate (mg/l P)	<0.01	<0.01	0.10	<0.01	<0.01
Calcium (mg/l)	76.8	<0.25	46.4	78.5	89.5
Magnesium (mg/l)	4.8	<0.25	2.8	5.2	4.8
Copper (mg/l)	<0.25	<0.25	<0.25	<0.25	<0.25
Zinc (mg/l)	<0.25	<0.25	<0.25	<0.25	<0.25
Iron (mg/l)					
PER CENT Organic	39.0	18.8	20.7	ND	25.2

Appendix 12. Water chemistry analyses for Station III outfall, sampled February 10, 1970.

SUBSTATION	A_2	B_2	C_2	D_2	E_2
PARAMETER					
Temperature (°C)	5	13	11	5	5
Dissolved Oxygen mg/l	12.4	10.3	11.9	12.5	12.6
pH Value	7.9	9.7	9.2	7.5	7.4
Specific Conductivity (micromhos/cm)	520	1,150	2,000	720	730
Turbidity (JTU)	29	95	55	30	30
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	554	276	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	196	860	680	198	200
Biochemical Oxygen Demand (BOD) (mg/l)	1.2	1.6		2.0	1.3
Chemical Oxygen Demand (COD) (mg/l)	8.0	12.0	28.0	4.0	7.8
Nitrates NO_3					
mg/l NO_3-N	0.8	>20	>20	4.0	3.2
mg/l NO_3	3.5	>88	>88	17.7	14.2
Phosphate PO_4 as Orthophosphate (mg/l P)	0.10	> 0.50	> 0.50	0.09	0.09
Hydrolyzable Phosphate (mg/l P)	0.05	< 0.01	< 0.01	0.03	0.03
Calcium (mg/l)	105.6	12.8	28.8	86.4	96.0
Magnesium (mg/l)	5.2	1.2	2.4	5.6	5.2
Copper (mg/l)	<0.25	<0.25	<0.25	<0.25	<0.25
Zinc (mg/l)	<0.25	<0.25	<0.25	<0.25	<0.25
Iron (mg/l)	<0.5	<0.5	<0.5	<0.5	<0.5
PER CENT Organic	39.4	24.1	22.0	30.2	30.2

Appendix 13. Water chemistry analyses for Station III outfall, sampled February 12, 1970.

SUBSTATION	A_3	B_3	C_3	D_3	E_3
PARAMETER					
Temperature (°C)	5	26	18	6	5
Dissolved Oxygen mg/l	12.7	7.8	12.8	12.6	11.8
pH Value	7.8	5.3	6.8	7.0	6.5
Specific Conductivity (micromhos/cm)	480	>8,000	5,500	650	900
Turbidity (JTU)	30	36	42	28	25
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	192	34.0	110	180	124
Biochemical Oxygen Demand (BOD) (mg/l)	<1.0	1.7	2.0	2.1	1.9
Chemical Oxygen Demand (COD) (mg/l)	<4.0	148	124	14.4	7.2
Nitrates NO_3					
mg/l NO_3-N	0.5	1.6	1.6	1.0	2.0
mg/l NO_3	2.2	7.1	7.1	4.4	8.9
Phosphate PO_4 as Orthophosphate (mg/l P)	0.12	0.18	>0.50	0.12	0.10
Hydrolyzable Phosphate (mg/l P)	0.07	<0.01	<0.01	0.03	0.05
Calcium (mg/l)	105.6	25.6	28.8	86.4	86.4
Magnesium (mg/l)	5.2	3.2	3.2	6.0	8.8
Copper (mg/l)	<0.25	<0.25	<0.25	<0.25	<0.25
Zinc (mg/l)	<0.25	<0.25	<0.25	<0.25	<0.25
Iron (mg/l)	<0.5	<0.5	<0.5	<0.5	<0.5
PER CENT Organic	39.4	19.4	23.7	31.7	26.0

Appendix 14. Water chemistry analyses for Station III outfall, sampled February 17, 1970.

SUBSTATION	A_4	B_4	C_4	D_4	E_4
PARAMETER					
Temperature (°C)	3	27	8	3	3
Dissolved Oxygen mg/l	12.2	7.5	11.7	12.1	12.0
pH Value	7.8	6.3	6.6	7.1	7.2
Specific Conductivity (micromhos/cm)	400	>8,000	1,350	650	700
Turbidity (JTU)	48	81	91	75	73
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	156	228	150	144	140
Biochemical Oxygen Demand (BOD) (mg/l)	3.7	1.0	3.8	3.7	2.8
Chemical Oxygen Demand (COD) (mg/l)	18.0	25.2	21.6	26.4	26.4
Nitrates NO_3					
mg/l NO_3-N	1.5	> 40.0	25.2	7.3	7.5
mg/l NO_3	6.6	>177	111.6	32.3	33.2
Phosphate PO_4 as Orthophosphate (mg/l P)	0.25	2.0	0.40	0.27	0.25
Hydrolyzable Phosphate (mg/l P)	0.10	0.12	<0.01	0.06	0.02
Calcium (mg/l)	67.2	19.2	70.4	64.0	76.8
Magnesium (mg/l)	4.0	2.8	4.4	4.4	4.0
Copper (mg/l)	<0.25	<0.25	<0.25	<0.25	<0.25
Zinc (mg/l)	<0.25	1.0	<0.25	<0.25	<0.25
Iron (mg/l)	<0.5	<0.5	<0.5	<0.5	<0.5
PER CENT Organic	28.8	17.9	21.4	20.4	26.2

Appendix 15. Water chemistry analyses for Station III outfall, sampled February 19, 1970.

SUBSTATION	A_5	B_5	C_5	D_5	E_5
PARAMETER					
Temperature (°C)	4	23	21	5	4
Dissolved Oxygen mg/l	12.2	7.8	8.0	11.9	11.6
pH Value	7.7	6.4	6.2	7.3	7.5
Specific Conductivity (micromhos/cm)	490	7,500	6,000	790	750
Turbidity (JTU)	31	92	76	47	47
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	180	86	96	170	186
Biochemical Oxygen Demand (BOD) (mg/l)	3.5	0.1	0.1	2.4	2.8
Chemical Oxygen Demand (COD) (mg/l)	22.0	26.4	26.4	26.4	13.2
Nitrates NO_3					
mg/l NO_3-N	0.5	30.0	22.4	2.2	2.1
mg/l NO_3	2.2	133.0	99.2	9.7	9.3
Phosphate PO_4 as Orthophosphate (mg/l P)	0.25	1.6	0.88	0.22	0.22
Hydrolyzable Phosphate (mg/l P)	0.02	<0.01	<0.01	0.18	0.03
Calcium (mg/l)	64.0	20.8	32.0	70.4	67.2
Magnesium (mg/l)	5.2	4.0	4.0	4.8	5.6
Copper (mg/l)	<0.25	<0.25	<0.25	<0.25	<0.25
Zinc (mg/l)	<0.25	0.50	0.30	<0.25	<0.25
Iron (mg/l)	<0.5	<0.5	<0.5	<0.5	<0.5
PER CENT Organic	48.3	19.8	18.6	26.2	24.0

Appendix 16. Water chemistry analyses for Station V outfall, sampled June 9, 1970.

SUBSTATION	E*$_1$	B$_1$	C$_1$	D$_1$	E$_1$
PARAMETER					
Temperature (°C)	25	25	25	25	
Dissolved Oxygen mg/l	3.6	6.4	4.2	5.0	4.8
pH Value	7.1	7.7	7.3	7.4	7.4
Specific Conductivity (micromhos/cm)	660	1,050	720	800	810
Turbidity (JTU)	23	14	24	18	17
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	214	298	220	236	236
Biochemical Oxygen Demand (BOD) (mg/l)	7.1	1/5-33.5 1/10-69.0	1/2-13.6 1/4-28.0	6.3	6.4
Chemical Oxygen Demand (COD) (mg/l)	38.2	72.1	46.6	46.6	42.4
Nitrates NO_3					
mg/l NO_3-N	0.6	6.0	1.4	2.8	2.8
mg/l NO_3	2.8	27.6	6.2	12.4	12.4
Phosphate PO_4 as Orthophosphate (mg/l P)	0.88	3.05	1.34	1.68	1.68
Hydrolyzable Phosphate (mg/l P)	0.05	0.10	<0.01	<0.01	<0.01
Calcium (mg/l)	64.0	48.0	60.0	56.0	60.0
Magnesium (mg/l)	6.6	6.6	6.8	7.0	7.4
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 17. Water chemistry analyses for Station V outfall, sampled June 11, 1970.

SUBSTATION	E^*_2	B_2	C_2	D_2	E_2
PARAMETER					
Temperature (°C)	25	25	25	25	25
Dissolved Oxygen mg/l	3.3	7.2	4.0	4.4	4.0
pH Value	7.1	7.3	7.3	7.3	7.4
Specific Conductivity (micromhos/cm)	740	1,020	770	820	830
Turbidity (JTU)	33	18	32	29	26
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	182	256	186	204	196
Biochemical Oxygen Demand (BOD) (mg/l)	6.2	1/5-4.5 1/10-14.0	1/2-7.8 1/4-13.6	3.4	4.0
Chemical Oxygen Demand (COD) (mg/l)	46.2	79.8	46.2	54.6	50.4
Nitrates NO_3					
mg/l NO_3-N	1.1	6.4	1.5	2.6	2.6
mg/l NO_3	4.9	29.4	6.6	11.5	11.5
Phosphate PO_4 as Orthophosphate (mg/l P)	1.08	4.35	1.48	2.00	2.15
Hydrolyzable Phosphate (mg/l P)	0.32	<0.01	<0.01	<0.01	<0.01
Calcium (mg/l)	60	52	60	58.0	56.0
Magnesium (mg/l)	6.8	7.4	7.0	7.0	7.0
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 18. Water chemistry analyses for Station V outfall, sampled June 16, 1970.

SUBSTATION	A^*_3	B_3	C_3	D_3	E_3
PARAMETER					
Temperature (°C)	27	26	27	27	27
Dissolved Oxygen mg/l	6.6	5.4	4.0	3.8	2.6
pH Value	7.6	7.5	7.5	7.5	7.5
Specific Conductivity (micromhos/cm)	850	975	925	925	925
Turbidity (JTU)	16	19	19	17	13
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	182	246	216	222	218
Biochemical Oxygen Demand (BOD) (mg/l)	6.0	1/10-3.0 1/50-	1/2-12.0 1/4- 7.2	1/2-11.2	1/2-11.8
Chemical Oxygen Demand (COD) (mg/l)	36.7	81.6	69.4	69.4	65.3
Nitrates NO_3					
mg/l NO_3-N	1.9	8.0	3.4	3.9	3.5
mg/l NO_3	8.4	35.4	15.1	17.3	15.5
Phosphate PO_4 as Orthophosphate (mg/l P)	0.10	9.20	4.45	4.60	4.65
Hydrolyzable Phosphate (mg/l P)	0.06	<0.01	<0.01	<0.15	0.01
Calcium (mg/l)	62.0	54.0	58.0	60.0	58.0
Magnesium (mg/l)	7.6	8.2	8.0	8.0	7.8
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 19. Water chemistry analyses for Station V outfall, sampled June 18, 1970.

SUBSTATION	A*$_2$	B*$_1$	C*$_1$	D*$_1$	E*$_3$
PARAMETER					
Temperature (°C)	29	28	29	30	30
Dissolved Oxygen mg/l	10.2		7.4	2.8	3.4
pH Value	7.8	7.6	7.8	7.8	7.8
Specific Conductivity (micromhos/cm)	775	1,100	850	850	850
Turbidity (JTU)	16	20	18	18	13
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	172	306	210	216	202
Biochemical Oxygen Demand (BOD) (mg/l)	5.7	1/10-34.0 1/50-	1/2-12.2 1/4-14.8	1/2-12.5	1/2-12.9
Chemical Oxygen Demand (COD) (mg/l)	39.2	144	65.4	74.1	56.7
Nitrates NO_3					
mg/l NO_3-N	1.0	0.4	1.0	0.6	0.5
mg/l NO_3	4.4	1.8	4.4	2.8	2.2
Phosphate PO_4 as Orthophosphate (mg/l P)	0.05	5.4	2.0	2.7	2.3
Hydrolyzable Phosphate (mg/l P)	0.03	0.40	0.30	0.20	0.40
Calcium (mg/l)	60	50.0	56.0	56.0	58.0
Magnesium (mg/l)	8.4	8.0	8.2	8.4	8.2
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 19. Continued

SUBSTATION	E^*_3	B_4	C_4	D_4	E_4
PARAMETER					
Temperature (°C)	30	29	30	30	30
Dissolved Oxygen mg/l	3.4	5.6	4.4	4.8	5.0
pH Value	7.8	7.6	7.8	7.8	7.8
Specific Conductivity (micromhos/cm)	850	1,100	850	875	850
Turbidity (JTU)	13	16	13	13	13
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	202	280	220	238	212
Biochemical Oxygen Demand (BOD) (mg/l)	1/2-12.9	1/10-10 1/50-	1/2-12.5 1/4- 8.8	1/2-12.2	1/2-10.8
Chemical Oxygen Demand (COD) (mg/l)	56.7	91.6	65.4	69.8	61.0
Nitrates NO_3					
mg/l NO_3-N	0.5	4.8	1.6	1.9	1.8
mg/l NO_3	2.2	21.3	7.2	8.6	8.0
Phosphate PO_4 as Orthophosphate (mg/l P)	2.3	4.6	3.4	3.5	3.8
Hydrolyzable Phosphate (mg/l P)	0.40	0.20	0.20	0.10	0.10
Calcium (mg/l)	58.0	50.0	56.0	54.0	56.0
Magnesium (mg/l)	8.2	8.2	8.4	8.4	8.4
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 20. Water chemistry analyses for Station V outfall, sampled June 20, 1970.

SUBSTATION	A*3	B*2	C*2	D*2	E*2
PARAMETER					
Temperature (°C)	29		29	29	29
Dissolved Oxygen mg/l	6.6	3.0	4.2	0.8	0.6
pH Value	7.8	7.5	7.6	7.6	7.6
Specific Conductivity (micromhos/cm)	1,250	1,000	1,175	1,200	1,200
Turbidity (JTU)	28	26	30	22	21
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	172	286	208	202	202
Biochemical Oxygen Demand (BOD) (mg/l)	3.7	1/10-15.0 1/50- 5.0	1/2- 6.9 1/4-11.6	1/2-12.4	1/2-12.4
Chemical Oxygen Demand (COD) (mg/l)	33.9	140.0	67.8	55.1	50.9
Nitrates NO_3					
mg/l NO_3-N	0.6	0.1	0.5	0.4	0.4
mg/l NO_3	2.8	0.1	2.2	1.7	1.7
Phosphate PO_4 as Orthophosphate (mg/l P)	0.02	8.0	2.9	2.6	2.5
Hydrolyzable Phosphate (mg/l P)	0.03	<0.01	<0.01	0.30	0.30
Calcium (mg/l)	68.0	48.0	60.0	62.0	64.0
Magnesium (mg/l)	9.2	8.0	8.8	8.8	9.2
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 20. Continued

SUBSTATION	E^*_4	B_5	C_5	D_5	E_5
PARAMETER					
Temperature (°C)	29	27	28	28	28
Dissolved Oxygen mg/l	0.6	5.6	2.6	2.6	2.0
pH Value	7.6	7.6	7.6	7.5	7.5
Specific Conductivity (micromhos/cm)	1,200	990	1,125	1,100	1,100
Turbidity (JTU)	21	16	20	21	17
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	202	242	218	216	220
Biochemical Oxygen Demand (BOD) (mg/l)	1/2-12.4	1/10-2.0 1/50-	1/2-10.8 1/4- 6.4	1/2-10.4	1/2-11.4
Chemical Oxygen Demand (COD) (mg/l)	50.9	80.6	55.4	55.4	63.6
Nitrates NO_3					
mg/l NO_3-N	0.4	6.0	2.1	2.6	2.0
mg/l NO_3	1.7	27.6	9.3	11.6	8.9
Phosphate PO_4 as Orthophosphate (mg/l P)	2.5	7.6	3.9	4.4	4.8
Hydrolyzable Phosphate (mg/l P)	0.30	0.20	< 0.01	0.60	0.80
Calcium (mg/l)	64.0	48.0	58.0	58.0	58.0
Magnesium (mg/l)	9.2	8.4	8.8	8.8	8.6
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 21. Water chemistry analyses for Station V outfall, sampled June 22, 1970.

SUBSTATION	A*4	B*3	C*3	D*3	E*5
PARAMETER					
Temperature (°C)	28	27	28	28	28
Dissolved Oxygen mg/l	7.0	4.6	5.4	3.2	3.8
pH Value	7.8	7.1	7.5	7.6	7.1
Specific Conductivity (micromhos/cm)	1,200	950	1,100	1,100	1,100
Turbidity (JTU)	23	20	23	17	14
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	164	220	180	174	176
Biochemical Oxygen Demand (BOD) (mg/l)	1/2-2.0	1/10- 8.0 1/50-10.0	1/2-9.4 1/4-3.6		1/4-3.2
Chemical Oxygen Demand (COD) (mg/l)	29.7	136.0	63.6	46.6	42.4
Nitrates NO_3					
mg/l NO_3-N	1.3	7.0	2.6	2.5	2.5
mg/l NO_3	5.8	31.0	11.5	11.1	11.1
Phosphate PO_4 as Orthophosphate (mg/l P)	0.07	9.6	3.8	2.7	2.7
Hydrolyzable Phosphate (mg/l P)	0.02	<0.01	0.10	0.30	0.10
Calcium (mg/l)	64.0	54.0	62.0	62.0	64.0
Magnesium (mg/l)	9.2	8.8	9.2	9.0	9.4
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 21. Continued

SUBSTATION	E^*_5	B_6	C_6	D_6	E_6
PARAMETER					
Temperature (°C)	28	26	27	27	27
Dissolv . Oxygen mg/l	3.8	7.0	5.4	4.6	3.4
pH Value	7.1	7.1	7.3	7.4	7.3
Specific Conductivity (micromhos/cm)	1,100	1,000	1,050	1,050	1,050
Turbidity (JTU)	14	13	14	15	12
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	176	202	198	188	188
Biochemical Oxygen Demand (BOD) (mg/l)	1/4-3.2	1/10- 1/50-	1/2-2.4 1/4-1.6	1/4-0.4	1/4-1.2
Chemical Oxygen Demand (COD) (mg/l)	42.4	72.1	59.4	63.6	59.4
Nitrates NO_3					
mg/l NO_3-N	2.5	11.0	6.6	5.8	5.7
mg/l NO_3	11.1	48.7	29.2	25.7	25.3
Phosphate PO_4 as Orthophosphate (mg/l P)	2.7	11.2	6.8	6.2	6.4
Hydrolyzable Phosphate (mg/l P)	0.10	<0.01	<0.01	<0.01	<0.01
Calcium (mg/l)	64.0	56.0	58.0	58.0	60.0
Magnesium (mg/l)	9.4	9.8	9.4	9.4	9.8
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 22. Water chemistry analyses for Station V outfall, sampled June 24, 1970.

SUBSTATION	A*5	B*4	C*4	D*4	E*6
PARAMETER					
Temperature (°C)	28	28	28	28	28
Dissolved Oxygen mg/l	4.8	5.6	4.8	3.2	2.8
pH Value	7.4	7.4	7.4	7.4	7.4
Specific Conductivity (micromhos/cm)	1,300	1,100	1,250	1,200	1,200
Turbidity (JTU)	28	43	37	29	28
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	170	278	196	208	206
Biochemical Oxygen Demand (BOD) (mg/l)	1/2-0.4	1/10- 1/50-	1/2- 1/4-5.2	1/4-11.2	1/4-3.6
Chemical Oxygen Demand (COD) (mg/l)	25.4	275.0	72.1	76.3	72.1
Nitrates NO_3					
mg/l NO_3-N	3.0	2.0	2.5	1.1	0.2
mg/l NO_3	13.3	8.9	11.5	4.9	0.9
Phosphate PO_4 as Orthophosphate (mg/l P)	0.10	10.4	3.0	4.0	3.8
Hydrolyzable Phosphate (mg/l P)	0.03	0.40	<0.01	<0.01	0.20
Calcium (mg/l)	70.0	48.0	62.0	62.0	62.0
Magnesium (mg/l)	9.4	8.0	9.2	8.8	9.2
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 22. Continued

SUBSTATION	E*6	B7	C7	D7	E7
PARAMETER					
Temperature (°C)	28	27	28	27	27
Dissolved Oxygen mg/l	2.8	6.2	4.2	4.2	4.6
pH Value	7.4	7.4	7.5	7.5	7.5
Specific Conductivity (micromhos/cm)	1,200	1,000	1,100	1,100	1,100
Turbidity (JTU)	28	23	26	20	18
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	206	244	228	222	224
Biochemical Oxygen Demand (BOD) (mg/l)	1/4-3.6	1/10- 1/50-	1/4-2.8	1/4-7.2	1/4-13.6
Chemical Oxygen Demand (COD) (mg/l)	72.1	102.0	89.0	84.8	84.8
Nitrates NO_3					
mg/l NO_3-N	0.2	5.6	3.8	3.0	2.7
mg/l NO_3	0.9	24.8	16.8	13.3	12.0
Phosphate PO_4 as Orthophosphate (mg/l P)	3.8	8.4	6.6	5.8	6.2
Hydrolyzable Phosphate (mg/l P)	0.20	<0.01	<0.01	<0.01	<0.01
Calcium (mg/l)	62.0	48.0	54.0	58.0	54.0
Magnesium (mg/l)	9.2	6.8	8.4	8.8	8.2
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 23. Water chemistry analyses for Station IX, sampled April 21, 1970.

SUBSTATION	A_1	B_1	C_1	D_1	E_1
PARAMETER					
Temperature (°C)	19	19	19	19	19
Dissolved Oxygen mg/l	9.0	9.0	9.4	9.4	9.4
pH Value	7.9	7.8	7.9	7.8	7.6
Specific Conductivity (micromhos/cm)	400	690	400	405	410
Turbidity (JTU)	45	19	48	48	47
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	118	176	138	136	138
Biochemical Oxygen Demand (BOD) (mg/l)	1.8	2.5	1.7	1.6	1.9
Chemical Oxygen Demand (COD) (mg/l)	16.6	19.9	16.6	16.6	16.6
Nitrates NO_3					
mg/l NO_3-N	0.2	0.5	0.4	0.7	0.1
mg/l NO_3	0.9	2.2	1.8	3.1	0.4
Phosphate PO_4 as Orthophosphate (mg/l P)	0.08	0.20	0.09	0.10	0.10
Hydrolyzable Phosphate (mg/l P)	0.01	0.02	<0.01	<0.01	0.01
Calcium (mg/l)	42	66	42	46	50
Magnesium (mg/l)	6.4	4.0	6.4	6.4	6.0
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.25	<0.25	<0.25	<0.25	<0.25
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 24. Water chemistry analyses for Station IX, sampled April 23, 1970.

SUBSTATION	A_2	B_2	C_2	D_2	E_2
PARAMETER					
Temperature (°C)	21	22	21	21	21
Dissolved Oxygen mg/l	8.6	9.0	9.0	9.0	9.0
pH Value	7.9	8.1	7.9	7.8	7.8
Specific Conductivity (micromhos/cm)	450	800	450	450	280
Turbidity (JTU)	40	16	40	38	40
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	138	202	160	148	134
Biochemical Oxygen Demand (BOD) (mg/l)	1.5	2.6	0.1	1.0	1.0
Chemical Oxygen Demand (COD) (mg/l)	10.0	16.6	10.0	13.3	13.3
Nitrates NO_3					
mg/l NO_3-N	0.6	1.0	0.4	0.3	0.5
mg/l NO_3	2.8	4.4	1.8	1.3	2.2
Phosphate PO_4 as Orthophosphate (mg/l P)	0.05	0.35	0.05	0.05	0.05
Hydrolyzable Phosphate (mg/l P)	<0.01	0.02	<0.01	<0.01	<0.01
Calcium (mg/l)	40.0	78.0	44.0	46.0	44.0
Magnesium (mg/l)	6.4	4.8	6.0	6.8	6.4
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.25	<0.25	<0.25	<0.25	<0.25
PER C	ND	ND	ND	ND	ND

Appendix 25. Water chemistry analyses for Station IX, sampled April 28, 1970.

SUBSTATION	A_3	B_3	C_3	D_3	E_3
PARAMETER					
Temperature (°C)	22	22	22	22	22
Dissolved Oxygen mg/l	8.8	8.2	9.4	8.4	8.8
pH Value	7.9	7.7	7.8	7.7	7.3
Specific Conductivity (micromhos/cm)	390	540	410	410	400
Turbidity (JTU)	63	43	55	63	61
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	138	126	138	134	142
Biochemical Oxygen Demand (BOD) (mg/l)	1.6	1.8	1.0	1.3	1.0
Chemical Oxygen Demand (COD) (mg/l)				22.4	22.4
Nitrates NO_3					
mg/l NO_3-N	<0.1	0.5	<0.1	<0.1	<0.1
mg/l NO_3	<0.4	2.2	<0.4	<0.4	<0.4
Phosphate PO_4 as Orthophosphate (mg/l P)	0.05	0.09	0.05	0.06	0.05
Hydrolyzable Phosphate (mg/l P)	0.01	0.01	0.01	<0.01	0.01
Calcium (mg/l)	52	60	50	50	52
Magnesium (mg/l)	5.6	3.6	5.2	5.6	5.6
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.25	<0.25	<0.25	<0.25	<0.25
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 26. Water chemistry analyses for Station IX, sampled May 6, 1970.

SUBSTATION	A_4	B_4	C_4	D_4	E_4
PARAMETER					
Temperature (°C)	20	20	20	20	20
Dissolved Oxygen mg/l	9.2	8.2	9.0	8.6	8.6
pH Value	7.4	7.6	7.5	7.6	7.6
Specific Conductivity (micromhos/cm)	400	725	405	410	405
Turbidity (JTU)	63	39	61	63	59
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	158	224	156	172	166
Biochemical Oxygen Demand (BOD) (mg/l)	1.4	2.8	1.2	1.5	1.5
Chemical Oxygen Demand (COD) (mg/l)	22.4	19.2	22.4	22.4	22.4
Nitrates NO_3					
mg/l NO_3-N	0.10	1.6	0.4	0.2	0.1
mg/l NO_3	0.44	7.1	1.8	0.89	0.44
Phosphate PO_4 as Orthophosphate (mg/l P)	0.08	0.30	0.10	0.09	0.10
Hydrolyzable Phosphate (mg/l P)	0.01	0.04	<0.01	<0.01	<0.01
Calcium (mg/l)	54.0	82.0	52.0	50	52.0
Magnesium (mg/l)	5.2	4.0	5.6	5.6	5.2
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.25	<0.25	<0.25	<0.25	<0.25
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 27. Water chemistry analyses for Station IX, sampled May 7, 1970.

SUBSTATION	A_5	B_5	C_5	D_5	E_5
PARAMETER					
Temperature (°C)	20	20	20	20	20
Dissolved Oxygen mg/l	9.2	9.0	9.2	9.4	9.4
pH Value	7.7	7.5	7.7	7.7	7.7
Specific Conductivity (micromhos/cm)	400	825	415	400	415
Turbidity (JTU)	61	41	61	63	62
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	156	228	170	174	154
Biochemical Oxygen Demand (BOD) (mg/l)	1.7	4.0	1.6	1.6	1.6
Chemical Oxygen Demand (COD) (mg/l)	13.0	17.3	13.0	17.3	13.0
Nitrates NO_3					
mg/l NO_3-N	0.1	1.8	0.1	0.2	0.1
mg/l NO_3	0.44	8.0	0.44	0.90	0.44
Phosphate PO_4 as Orthophosphate (mg/l P)	0.09	0.42	0.1	[illegible]	0.09
Hydrolyzable Phosphate (mg/l P)	<0.01	<0.01	<0.01	<0.01	<0.01
Calcium (mg/l)	48.0	82.0	50.0	46.0	50.0
Magnesium (mg/l)	4.8	4.0	5.2	5.6	5.6
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.25	<0.25	<0.25	<0.25	<0.25
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 28. Water chemistry analyses for Station X, sampled May 20, 1970.

SUBSTATION	A_1	B_1	C_1	D_1	E_1
PARAMETER					
Temperature (°C)	24	25	24	24	24
Dissolved Oxygen mg/l	8.8	11.0	8.8	9.0	9.0
pH Value	7.7	7.9	7.8	7.8	7.8
Specific Conductivity (micromhos/cm)	480	900	495	495	495
Turbidity (JTU)	36	10	36	36	37
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	146	270	154	144	148
Biochemical Oxygen Demand (BOD) (mg/l)	2.3	7.1	2.7	2.6	2.8
Chemical Oxygen Demand (COD) (mg/l)	20	44	20	20	16
Nitrates NO_3					
mg/l NO_3-N	1.0	0.2	0.5	1.0	1.0
mg/l NO_3	4.4	0.88	2.2	4.4	4.4
Phosphate PO_4 as Orthophosphate (mg/l P)	0.04	1.32	0.04	0.04	0.03
Hydrolyzable Phosphate (mg/l P)	<0.01	<0.01	0.02	<0.01	0.02
Calcium (mg/l)	58.0	102.0	58.0	58.0	58.0
Magnesium (mg/l)	7.4	12.8	6.8	6.8	6.8
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 29. Water chemistry analyses for Station X, sampled May 22, 1970.

SUBSTATION	A_2	B_2	C_2	D_2	E_2
PARAMETER					
Temperature (°C)	24	23	24	24	25
Dissolved Oxygen mg/l	6.2	9.0	6.6	6.6	6.8
pH Value	7.3	7.6	7.4	7.2	7.3
Specific Conductivity (micromhos/cm)	690	850	700	700	700
Turbidity (JTU)	24	4	25	26	25
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	146	280	152	148	148
Biochemical Oxygen Demand (BOD) (mg/l)	2.0	2.9	1.9	2.0	2.2
Chemical Oxygen Demand (COD) (mg/l)	20	20	16	16	12
Nitrates NO_3					
mg/l NO_3-N	1.1	0.5	1.2	1.1	1.2
mg/l NO_3	4.9	2.2	5.3	4.9	5.3
Phosphate PO_4 as Orthophosphate (mg/l P)	0.04	1.02	0.05	0.07	0.05
Hydrolyzable Phosphate (mg/l P)	0.03	0.08	0.04	0.02	0.04
Calcium (mg/l)	58.0	100.0	62.0	62.0	60.0
Magnesium (mg/l)	7.4	12.0	8.0	8.0	8.0
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 30. Water chemistry analyses for Station X, sampled May 25, 1970.

SUBSTATION	A_3	B_3	C_3	D_3	E_3
PARAMETER					
Temperature (°C)	25	24	25	25	25
Dissolved Oxygen mg/l	6.4	9.0	7.0	7.0	7.0
pH Value	7.1	7.8	7.3	7.2	7.4
Specific Conductivity (micromhos/cm)	790	740	770	780	780
Turbidity (JTU)	17	10	18	18	18
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	166	226	182	172	168
Biochemical Oxygen Demand (BOD) (mg/l)	2.6	1/2- 8.6 1/4-16.4	3.2	3.4	3.6
Chemical Oxygen Demand (COD) (mg/l)	23.8	59.4	27.7	27.7	27.7
Nitrates NO_3					
mg/l NO_3-N	0.6	0.5	0.6	0.5	0.6
mg/l NO_3	2.8	2.2	2.8	2.2	2.8
Phosphate PO_4 as Orthophosphate (mg/l P)	0.04	1.20	0.29	0.16	0.15
Hydrolyzable Phosphate (mg/l P)	0.01	0.04	<0.01	0.04	0.03
Calcium (mg/l)	60.0	62.0	62.0	62.0	66.0
Magnesium (mg/l)	6.8	9.6	8.0	8.0	7.4
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 31. Water chemistry analyses for Station X, sampled May 27, 1970.

SUBSTATION	A_4	B_4	C_4	D_4	E_4
PARAMETER					
Temperature (°C)	24	23	24	24	25
Dissolved Oxygen mg/l	5.0	6.8	5.2	5.6	5.8
pH Value	7.4	7.4	7.3	7.4	7.4
Specific Conductivity (micromhos/cm)	690	470	690	690	690
Turbidity (JTU)	28	45	32	31	31
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	180	160	180	180	178
Biochemical Oxygen Demand (BOD) (mg/l)	5.7	1/1- 6.7 1/2-13.6	6.0	6.1	6.4
Chemical Oxygen Demand (COD) (mg/l)	24.5	40.8	24.5	24.5	28.6
Nitrates NO_3					
mg/l NO_3-N	1.0	1.1	1.0	1.0	1.0
mg/l NO_3	4.4	4.9	4.4	4.4	4.4
Phosphate PO_4 as Orthophosphate (mg/l P)	0.05	0.40	0.07	0.05	0.05
Hydrolyzable Phosphate (mg/l P)	0.05	0.04	0.03	0.07	0.05
Calcium (mg/l)	62	54.0	62.0	66.0	66.0
Magnesium (mg/l)	7.2	5.8	6.8	6.8	6.8
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 32. Water chemistry analyses for Station X, sampled May 29, 1970.

SUBSTATION	A_5	B_5	C_5	D_5	E_5
PARAMETER					
Temperature (°C)	24	24	24	25	25
Dissolved Oxygen mg/l	6.6	8.2	7.0	7.0	7.2
pH Value	7.3	7.6	7.4	7.4	7.4
Specific Conductivity (micromhos/cm)	650	450	610	625	625
Turbidity (JTU)	33	15	34	34	34
Alkalinity					
phenolphthalein alkalinity (mg/l as $CaCO_3$)	0.0	0.0	0.0	0.0	0.0
total alkalinity (mg/l as $CaCO_3$)	172	156	162	168	164
Biochemical Oxygen Demand (BOD) (mg/l)	4.3	1/1-2.1 1/2-7.2	4.6	4.6	4.6
Chemical Oxygen Demand (COD) (mg/l)	25.9	21.6	25.9	25.9	25.9
Nitrates NO_3					
mg/l NO_3-N	1.2	0.7	1.2	1.2	1.4
mg/l NO_3	5.3	3.1	5.3	5.3	6.2
Phosphate PO_4 as Orthophosphate (mg/l P)	0.09	0.25	0.10	0.10	0.08
Hydrolyzable Phosphate (mg/l P)	0.01	0.01	0.04	0.02	0.04
Calcium (mg/l)	58.0	54.0	60.0	58.0	60.0
Magnesium (mg/l)	5.8	5.2	5.8	5.6	5.8
Copper (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Zinc (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
Iron (mg/l)	<0.125	<0.125	<0.125	<0.125	<0.125
PER CENT Organic	ND	ND	ND	ND	ND

Appendix 33. Summary of benthos above Station I outfall.

Taxa	Number of Organisms										Total
Samples	1	2	3	4	5	6	7	8	9	10	
Hydroida			13	3	9	675	343	17	1		1,061
Tricladida						1				4	5
Nematoda	2	12	7	14	1	168	34	70	7	6	321
Oligochaeta	60	42	68	45	61	232	115	71	88	60	842
Hirudinea			1			2					3
Cladocera		1	2	1		25	22	8	6	38	103
Ostracoda			1	3		7	5	9	2		27
Calanoida				7	3	2					12
Cyclopoida	3	4	71	32	3	111	79	55	32	149	539
Harpacticoida						1	2	1	2	1	7
Amphipoda						1					1
Coleoptera										3	3
Diptera		1	4	3	2	104	47	42	6	7	216
Gastropoda			1			10	40	3		2	56
*Oligochaete cocoons						4	3				
Total individuals	65	60	168	108	79	1,339	687	276	144	270	3,196
Total taxa	3	5	9	8	6	13	9	9	8	9	14

*Totals do not include Oligochaete cocoons

Appendix 34. Summary of benthos at Station I outfall.

Taxa	Number of Organisms										Total
Samples	1	2	3	4	5	6	7	8	9	10	
Hydroida			57	8	5	3	11	4	7	16	111
Nematoda				1					1	2	4
Oligochaeta	8	10	36	15	11	4	13	3	10	22	132
Cladocera	26	55					1		2		84
Ostracoda	64	20								1	85
Cyclopoida	64	100	6	1	11	5	17	4	7	23	238
Diptera	9	7	6	4	4	1	4	2	12	23	72
Gastropoda	1		2	1					1	4	9
Total individuals	172	192	107	30	31	13	46	13	40	91	735
Total taxa	6	5	5	6	4	4	5	4	7	7	8

Appendix 35. Summary of benthos 70 yards below Station I outfall.

Taxa	Number of Organisms										Total
Samples	1	2	3	4	5	6	7	8	9	10	
Foraminifera	2		1		1	1					5
Hydroida					74			25	2	1	102
Nematoda	2	1	5	1			4	4	41	15	73
Oligochaeta	52	33	136	119	172	88	82	59	213	146	1,100
Hirudinea					1						1
Cladocera				1			5	1	2		9
Ostracoda					1	2	2	2			7
Cyclopoida	1				6		1	5	4		17
Coleoptera	1										1
Diptera	21	19	39	13	5			2	3	1	103
Pelecypoda					1	1					2
*Oligochaete cocoons	1				2						
Total individuals	79	53	181	134	261	92	94	98	265	163	1,420
Total taxa	6	3	4	4	8	4	5	7	6	4	11

*Totals do not include Oligochaete cocoons

Appendix 36. Summary of benthos 150 yards below Station I outfall.

Taxa	Number of Organisms										Total
Samples	1	2	3	4	5	6	7	8	9	10	
Hydroida					5	24	9	21			59
Nematoda					2	4	17	40	11	20	94
Oligochaeta	13	7		3	39	13	10	8	10	10	113
Cladocera	2				3	2			2		9
Ostracoda						3					3
Cyclopoida	1	1		1	2	4	2	2	27	49	89
Diptera					3	7	1	6	6	7	30
Hydracarina										1	1
Gastropoda						1	1		4	1	7
Total individuals	16	8	0	4	54	58	40	77	60	88	405
Total taxa	3	2	0	2	6	8	6	5	6	6	9

Appendix 37. Summary of benthos above Station II outfall.

Taxa	Number of Organisms										Total
Samples	1	2	3	4	5	6	7	8	9	10	
Foraminifera					1		1				2
Nematoda			1		1		1				3
Oligochaeta	39	63	13	17	119	86	139	28	56	23	583
Cladocera					1			2			3
Ostracoda					6	2		3	6		17
Calanoida								2			2
Cyclopoida					3		1	2			6
Diptera			3	2	2	1	1		1	1	11
*Oligochaete cocoons					1						
Total individuals	39	63	17	19	133	89	143	37	63	24	627
Total taxa	1	1	3	2	7	3	5	5	3	2	8

*Totals do not include Oligochaete cocoons

Appendix 38. Summary of benthos at Station II outfall.

Taxa	Number of Organisms										Total
Samples	1	2	3	4	5	6	7	8	9	10	
Oligochaeta	18	63	60	114	66	108	185	121	122	14	871
Cladocera									1		1
Cyclopoida					1	2		1	2		6
Coleoptera							1				1
Diptera		1	1					1	2		5
Gastropoda				2							2
Total individuals	18	64	61	116	67	110	186	123	127	14	886
Total taxa	1	2	2	2	2	2	2	3	4	1	6

Appendix 39. Summary of benthos 70 yards below Station II outfall.

Taxa	Number of Organisms										Total
Samples	1	2	3	4	5	6	7	8	9	10	
Foraminifera				1		1					2
Oligochaeta	20	34	4	18	119	77	110	197	124	3	706
Cladocera							1				1
Ostracoda				1			2				3
Cyclopoida				1							1
Diptera	1		1	1		1	5	5		6	20
Total individuals	21	34	5	22	119	79	118	202	124	9	733
Total taxa	2	1	2	5	1	3	4	2	1	2	6

Appendix 40. Summary of benthos 600 yards below Station II outfall.

Taxa	Number of Organisms										Total
Samples	1	2	3	4	5	6	7	8	9	10	
Foraminifera				1		1					2
Nematoda	1										1
Oligochaeta	136	48	218	260	168	126	45	32	69	68	1,170
Cladocera			1								1
Ostracoda			1								1
Cyclopoida	5		18	1		1		2			27
Diptera	1		2	1	1		2	2			9
Gastropoda	4										4
Total individuals	147	48	240	263	169	128	47	36	69	68	1,215
Total taxa	5	1	5	4	2	3	2	3	1	1	8

Appendix 41. Summary of benthos above Station III outfall.

Taxa	Number of Organisms										Total
Samples	1	2	3	4	5	6	7	8	9	10	
Nematoda		2		4	3	1	2	1	3	2	18
Oligochaeta	8	6		44	21	27	46	23	21	13	209
Calanoida				1							1
Cyclopoida		1		3	3			1	1	4	13
Ephemeroptera				1	1						2
Coleoptera				1							1
Trichoptera					1						1
Diptera	10	19	22	47	26	6	7	7	8	22	174
Hydracarina				1	1		1				3
Gastropoda		1					2				3
Total individuals	18	29	22	102	56	34	58	32	33	41	425
Total taxa	2	5	1	8	7	3	5	4	4	4	10

Appendix 42. Summary of benthos at Station III outfall.

Taxa	Number of Organisms										Total
Samples	1	2	3	4	5	6	7	8	9	10	
Rhabdocoela										2	2
Nematoda						7	3	10	8	4	32
Bryozoa						1				1	2
Oligochaeta						53	23	8	8	14	106
Calanoida						1	1		3		5
Cyclopoida								1		3	4
Harpacticoida						1					1
Ephemeroptera										5	5
Coleoptera								1	1		2
Trichoptera						1					1
Diptera					19	18	16	39	38	48	178
Hydracarina								2			2
Gastropoda								2		1	3
Total individuals	0	0	0	0	19	82	43	63	58	78	343
Total taxa	0	0	0	0	1	7	4	7	5	8	13

Appendix 43. Summary of benthos 30 yards below Station III outfall.

Taxa	Number of Organisms										Total
Samples	1	2	3	4	5	6	7	8	9	10	
Nematoda						1	1		6	5	13
Bryozoa							1	1			2
Oligochaeta	2						9	4	10	16	41
Hirudinea								1			1
Cyclopoida					1		4				10
Coleoptera							1		1		2
Trichoptera						1					1
Diptera					2	8	20				30
Hydracarina							3				3
*Gastropod egg cases							2				
Total individuals	2	0	0	0	3	15	39	6	17	21	103
Total taxa	1	0	0	0	2	4	7	3	3	2	9

*Not counted in totals

Appendix 44. Summary of benthos 150 yards below Station III outfall.

Taxa	Number of Organisms										Total
Samples	1	2	3	4	5	6	7	8	9	10	
Rhabdocoela										1	1
Nematoda				3	2	9	1	5	8	7	35
Oligochaeta		1			11	14	5	18	4	12	65
Cyclopoida	5	2		3	7	18		10	28	16	89
Ephemeroptera									1		1
Coleoptera									1	1	2
Diptera	7	5	8	8	9	37	26	15	33	40	188
Hydracarina										1	1
Gastropoda			1					1		1	3
Total individuals	12	8	9	14	29	78	32	49	75	79	385
Total taxa	2	3	2	3	4	4	3	5	6	8	9

Appendix 45. Summary of benthos above Station V outfall.

Taxa	Number of Organisms										Total
Samples	1	2	3	4	5	6	7	8	9	10	
Nematoda	108	1						2	1	149	261
Oligochaeta	293	209	51	63	100	1		90	5	157	969
Coleoptera	1										1
Trichoptera	3										3
Diptera	3	4		1	14	4	3	2			31
Gastropoda	32	16	6	1					2+	19	74
*Oligochaete cocoons	86	47	9	4	3	1				20	
Total individuals	440	230	57	65	114	5	3	94	6	325	1,339
Total taxa	6	4	2	3	2	2	1	3	2	3	6

+Dead individuals - not counted in totals

*Not counted in totals

Appendix 46. Summary of benthos at Station V outfall.

Taxa	Number of Organisms										Total
Samples	1	2	3	4	5	6	7	8	9	10	
Nematoda						21	-	-	-	-	21
Oligochaeta	4			1		3	-	-	-	-	8
Cyclopoda					1		-	-	-	-	1
Diptera			1			2	-	-	-	-	3
Gastropoda	16+	99+	5+	3+	1+		-	-	-	-	
Total individuals	4	0	1	1	1	26	-	-	-	-	33
Total taxa	1	0	1	1	1	3	-	-	-	-	4

+Dead individuals - not counted in totals

-Samples 7 - 10 not taken

Appendix 47. Summary of benthos above tributary at Station IX.

Taxa	Number of Organisms										Total
Samples	1	2	3	4	5	6	7	8	9	10	
Nematoda	1		1								2
Oligochaeta	10	20	11	9	5	11	7	2	11	8	94
Hirudinea			1								1
Cladocera										1	1
Cyclopoida	2	2		1	3						8
Ephemeroptera	1			2	1	1					5
Odonata		1	2								3
Coleoptera			1								1
Trichoptera							2		2		4
Diptera	22	76	11	87	96	51	13	17	28	6	407
Gastropoda	1	1			4						6
Total individuals	37	100	27	99	109	63	22	19	41	15	532
Total taxa	6	5	6	4	5	3	3	2	3	3	11

Appendix 48. Summary of benthos at mouth of tributary at Station IX.

Taxa	Number of Organisms										Total
Samples	1	2	3	4	5	6	7	8	9	10	
Oligochaeta	71	245	80	23	7	5	5	6	3	1	446
Hirudinea		1									1
Cyclopoida	1	1				1	2				5
Hemiptera		1									1
Diptera	27	24	88	59	6	8	39	24	2	2	279
Gastropoda			2		2	1	3				8
Total individuals	99	272	170	82	15	15	49	30	5	3	740
Total taxa	3	5	3	2	3	4	4	2	2	2	6

Appendix 49. Summary of benthos 30 yards below mouth of tributary at Station IX.

Taxa	Number of Organisms										Total
Samples	1	2	3	4	5	6	7	8	9	10	
Nematoda	1	1	1								3
Oligochaeta	214	67	90	45	32	83	7	12	2	10	562
Hirudinea	2	1									3
Cladocera	3										3
Cyclopoida	25	6	7	1	3	4					46
Trichoptera						1			1	1	3
Diptera	63	31	33	126	63	93	53	23	15	17	517
Gastropoda	4	5	2	4	4			1	1	2	23
Total individuals	312	111	133	176	102	181	60	36	19	30	1,160
Total taxa	7	6	5	4	4	4	2	3	4	4	8

Appendix 50. Summary of benthos 150 yards below mouth of tributary at Station IX.

Taxa	Number of Organisms										Total
Samples	1	2	3	4	5	6	7	8	9	10	
Nematoda	1		1	1				1			4
Oligochaeta	105	63	15	5	17	30	36	46	1	3	321
Hirudinea	1		3	4	1						9
Ostracoda							1				1
Cyclopoida	1	2	1	4	6	2	5	4		1	26
Trichoptera		1									1
Diptera	19	47	29	32	28	15	18	21	21	1	231
Gastropoda		2	1	4	2	6	2	3	1	1	22
*Oligochaete cocoons	2							2			
Total individuals	127	115	50	50	54	53	62	75	23	6	615
Total taxa	5	5	6	6	5	4	5	5	3	4	8

*Not included in totals

Appendix 51. Summary of benthos above mouth of tributary at Station X.

Taxa	Number of Organisms										Total
Samples	1	2	3	4	5	6	7	8	9	10	
Foraminifera					2			1			3
Nematoda		1						1	1	1	4
Oligochaeta	41	79	13	38	77	57	73	75	163	95	711
Hirudinea									1	1	2
Cladocera			1								1
Calanoida						1					1
Cyclopoida	1						1	3	1		6
Diptera	1	5	17	33	1	1	53	83	13	6	213
Gastropoda									2		2
Total individuals	43	85	31	71	80	59	127	163	181	103	943
Total taxa	3	3	3	2	3	3	3	5	6	4	9

Appendix 52. Summary of benthos at mouth of tributary at Station X.

Taxa	Number of Organisms										Total
Samples	1	2	3	4	5	6	7	8	9	10	
Foraminifera		1									1
Nematoda	4	4	3	2		2				1	16
Oligochaeta	81	61	121	40	53	132	66	85	19	17	675
Cyclopoida	1	2				1					4
Diptera	6	16	7	4		15	9	88	150	67	362
Gastropoda		3	3								6
*Oligochaete cocoons	1	2	2	2							
Total individuals	92	87	134	46	53	150	75	173	169	85	1,064
Total taxa	4	6	4	3	1	4	2	2	2	3	6

*Not included in totals

Appendix 53. Summary of benthos 70 yards below mouth of tributary at Station X.

Taxa	Number of Organisms										Total
Samples	1	2	3	4	5	6	7	8	9	10	
Nematoda			1								1
Oligochaeta	23	18	44	23	64	101	59	12	72	112	528
Cyclopoida	1	1		1							3
Isopoda		1									1
Ephemeroptera			1								1
Diptera	150	60	232	76	40	14	18	23	14	4	631
Gastropoda	3	1			2	1			1		8
Total individuals	177	81	278	100	106	116	77	35	87	116	1,173
Total taxa	4	5	4	3	3	3	2	2	3	2	7

Appendix 54. Summary of benthos 150 yards below mouth of tributary at Station X.

Taxa	Number of Organisms										Total
Samples	1	2	3	4	5	6	7	8	9	10	
Foraminifera					2	3		1			6
Nematoda			3					2	4	6	15
Oligochaeta	17	18	329	203	76	31	56	111	48	42	931
Cladocera			1								1
Cyclopoida							2	3	1	1	7
Diptera	2	18	33	42	2	1		5	3	3	109
Hydracarina								1			1
Gastropoda		2		1	1	2					6
*Oligochaete cocoons			2				1				
Total individuals	19	38	366	246	81	37	58	123	56	52	1,076
Total taxa	2	3	4	3	4	4	2	6	4	4	8

Appendix 55. Rainfall distribution in inches for 1969, 1970 and 1971.

	1969		1970		1971	
	Total	Departure	Total	Departure	Total	Departure
January	1.26	-0.78	0.72	-1.32	0.19	-1.85
February	1.99	-0.25	4.78	+2.54	1.32	-0.92
March	3.62	+1.11	3.49	+0.98	0.34	-2.17
April	3.40	-0.20	4.68	+1.08	2.76	-0.84
May	7.12	+2.53	3.62	-0.96	1.88	-2.70
June	0.63	-2.35	0.61	-2.37	0.83	-2.14
July	0.77	-0.98	0.94	-0.81	3.60	+1.85
August	2.56	+0.88	6.85	+5.17		
September	4.55	+2.01	6.25	+3.71		
October	5.82	+3.23	2.95	+0.36		
November	1.22	-1.24	0.20	-2.26		
December	2.75	+0.40	1.01	-1.34		
Annual	35.69	+4.36	36.10	+4.77		

(Taken from Annual Summary, Climatological Data, Department of Commerce.)

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16. Abstract Toxicity of industrial effluents discharged directly into or in close proximity to the Trinity River was reflected through a 27-month period. The investigation was concerned with four aspects--bioassay, growth and development, chemistry and benthos.

Three industries contributed toxic materials which had a significant influence on the surrounding aquatic community. Toxicity ranges were established for the respective effluents using mature minnows, fry and spawn. Fry surviving 96-hour exposure to some of the effluents later developed orientation problems and varied noticeably in growth. Fry were only slightly less resistant to the effluents than minnows, but were judged to be reasonably reliable bioassay test organisms. Effluents from a railroad equipment cleaning area, a plant producing cracking catalysts used in processing combustion engine fuels and a sewage treatment plant influenced the water quality of the river downstream from the outfalls. The ranges of nitrates, phosphates, biochemical oxygen demand and specific conductance for the river were increased by the effluents.

Environmental stress was detected at the railroad equipment cleaning area outfall and even more at the plant producing cracking catalysts. Benthos were not able to live in the flocculent material discharged in the latter effluent. The drastic reduction in invertebrates at the sewage treatment plant is believed to have resulted from the chlorinated effluent.

This report was submitted in fulfillment of Project Number 18050 DBB under the sponsorship of the Water Quality Office of the Environmental Protection Agency.

17a. Descriptors
*Bioassay, *Water quality, *Industrial effluents, *Water pollution, *Toxicity, *Sewage effluents, *Benthic fauna, *Seston, *Fish, Minnows, Fry, Channel catfish, Shiners, Bass, Sunfish, Fish eggs, Trace metals, Biochemical oxygen demand, Chemical oxygen demand, Conductivity, Food processing wastes, Acid wastes.

17b. Identifiers
*Fish development, *Abioseston, *Bioseston, *Fort Worth, Texas, *Trinity River, *Tarrant County, Quantitative study, Distribution, Invertebrates, Turbidity, River discharge, Food processing wastes, Dissolved oxygen.

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